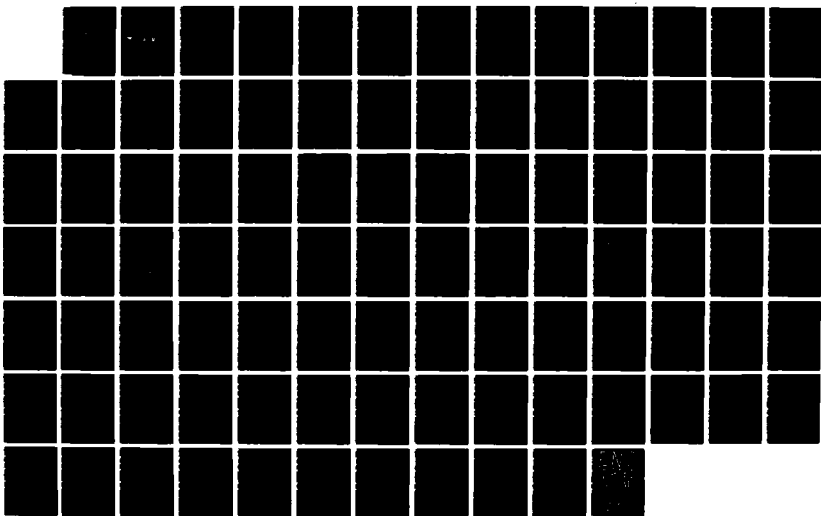
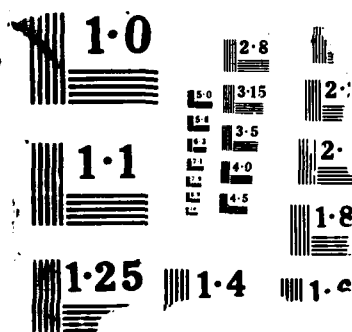


HD-A195 467 COMPUTER PROGRAMS FOR GENERATION OF NASTRAM AND VIBRA-6 1/1  
AIRCRAFT MODELS(U) ANAMET LABS INC HAYWARD CA  
S G HARRISON APR 88 1286-1A AFWL-TR-87-21  
UNCLASSIFIED F33615-84-C-3216 F/G 12/5 NL





AD-A195 467



## COMPUTER PROGRAMS FOR GENERATION OF NASTRAN AND VIBRA-6 AIRCRAFT MODELS

Steven G. Harris

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April 1988

Final Report



Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY  
Air Force Systems Command  
Kirtland Air Force Base, NM 87117-6008

This final report was prepared by the Anamet Laboratories, Inc., Haywood, California, under contract F33615-84-C-3216, with the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico. Elena Franklin (AFWL/NTAT) was the Laboratory Project Officer-in-Charge.

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REPORT DOCUMENTATION PAGE				
1a REPORT SECURITY CLASSIFICATION		1b RESTRICTIVE MARKINGS		
2a SECURITY CLASSIFICATION AUTHORITY		3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.		
2b DECLASSIFICATION / DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 1286.1A		5 MONITORING ORGANIZATION REPORT NUMBER(S) AFWL-TR-87-21		
6a. NAME OF PERFORMING ORGANIZATION Anamet Laboratories, Inc.		6b OFFICE SYMBOL (if applicable)		7a NAME OF MONITORING ORGANIZATION Air Force Weapons Laboratory
6c. ADDRESS (City, State, and ZIP Code) 3400 Investment Boulevard Hayward, California 94545-3811		7b ADDRESS (City, State, and ZIP Code) Kirtland Air Force Base, New Mexico 87117-6008		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b OFFICE SYMBOL (if applicable)		9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-84-C-3216
8c. ADDRESS (City, State, and ZIP Code)		10 SOURCE OF FUNDING NUMBERS		
		PROGRAM ELEMENT NO. 62601F	PROJECT NO. 8809	TASK NO. 03 WORK UNIT ACCESSION NO. 26
11 TITLE (Include Security Classification) COMPUTER PROGRAMS FOR GENERATION OF NASTRAN AND VIBRA-6 AIRCRAFT MODELS				
12. PERSONAL AUTHOR(S) Harris, Steven G.				
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM 12/85 TO 12/86	14. DATE OF REPORT (Year, Month, Day) 1988, April		15 PAGE COUNT 96
16. SUPPLEMENTARY NOTATION				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) NASTRAN Modeling VIBRA-6 Ritz Procedure Aircraft Blast Response	
FIELD	GROUP	SUB-GROUP		
12	05			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report describes a series of computer programs designed to aid the analyst in preparing input data for aircraft models to be analyzed using NASTRAN and/or VIBRA-6. The programs permit creation of either beam or plate-type models of aircraft, subsequent postprocessing of NASTRAN OUTPUT2 files, and creation of VIBRA-6 AERO, IMOD and LOAD fixed data decks. In addition, the analyst may specify use of either the Ritz procedure or standard NASTRAN eigensolvers to derive normal modes of the aircraft for use in the VIBRA-6 vulnerability assessment. A command procedure is provided to orchestrate the execution of the various programs, to keep track of file assignments and to maintain a history of program use. <i>Keywords: Blast resistance; vulnerability; VIBRA-6; NASTRAN; computer programs; input data; output data; postprocessing; Ritz procedure; eigensolvers; normal modes; vulnerability assessment; command procedure; file assignments; history of program use.</i>				
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Elena Franklin		22b. TELEPHONE (Include Area Code) (505) 844-0311		22c. OFFICE SYMBOL NTATE

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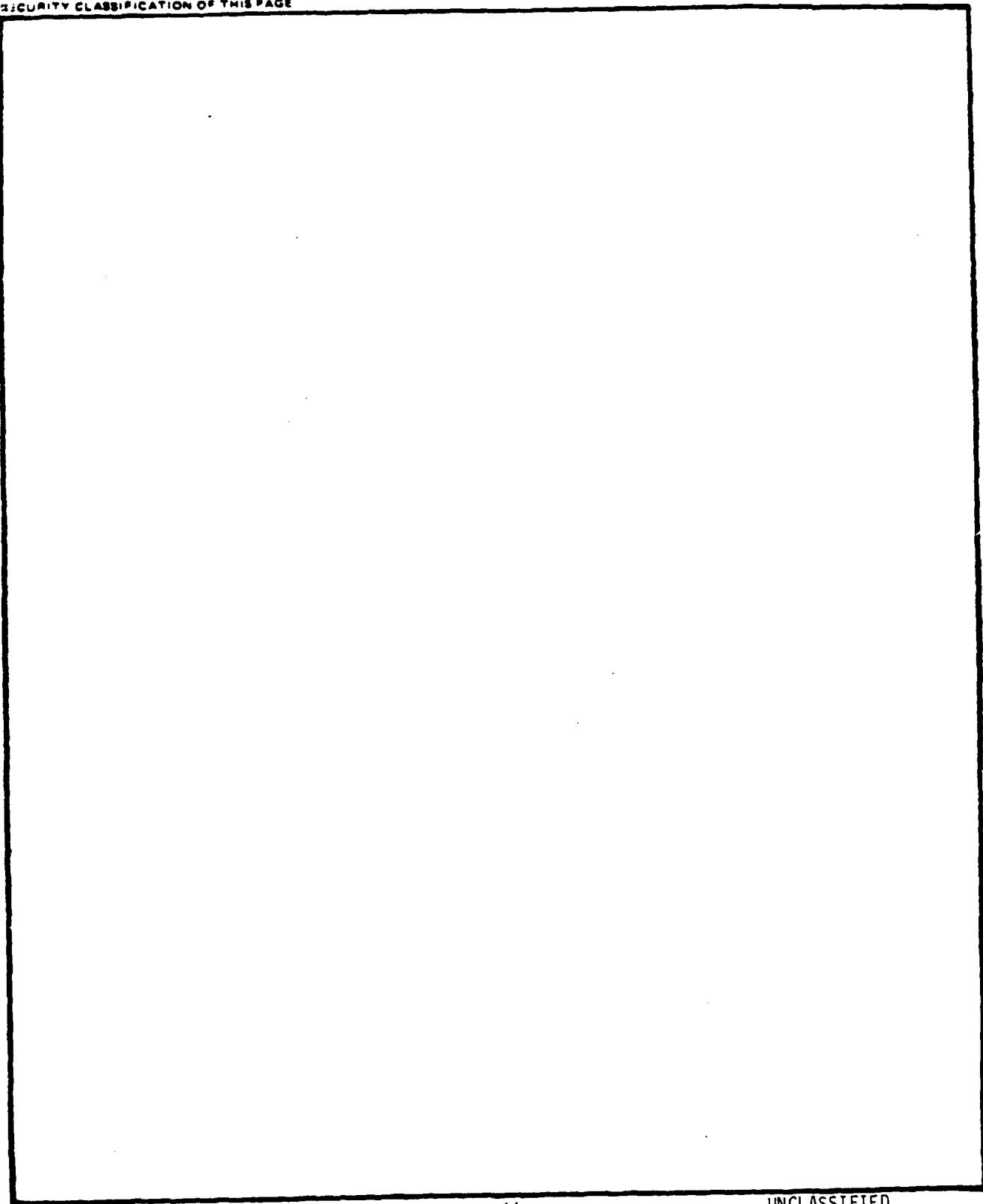
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## PREFACE

This report describes a series of computer programs designed to aid the analyst in preparing input data for aircraft models to be analyzed using NASTRAN and/or VIBRA-6. The programs permit creation of either beam or plate-type models of aircraft, subsequent postprocessing of NASTRAN OUTPUT2 files, and creation of VIBRA-6 AERO, IMOD, and LOAD fixed data decks. In addition, the analyst may specify use of either the Ritz procedure or standard NASTRAN eigensolvers to derive normal modes of the aircraft for use in the VIBRA-6 vulnerability assessment. A command procedure is provided to orchestrate the execution of the various programs, to keep track of file assignments and to maintain a history of program use.

For simplicity, the names of computers, terms, programs, plotting packages, sub-routines, decks, and procedures are defined after the Reference Section at the end of the report.



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# 1 BACKGROUND

The VIBRA-6 computer program, Refs. 1 and 2, is used to evaluate the vulnerability of aircraft structures to gust loads induced by nuclear blast. VIBRA-6 input is divided into a fixed data deck and a run data deck. The fixed data deck is the principal input to the program, and it describes the structural, aerodynamic, and load models of the aircraft. Modal data (frequencies, mode shapes, and damping) are provided separately for the structural and aerodynamic models of the aircraft. A loads model is also input separately to recover peak forces and moments in the airframe structure. The run data deck, which specifies the type of VIBRA-6 analysis to be performed and the associated blast conditions, is a minor and simple part of the overall required input. The task of translating raw NASTRAN analysis results into a form required for the VIBRA-6 fixed data deck is formidable, however, and is one which is best suited to an automated procedure that interfaces model creation and structural analysis programs with VIBRA-6.

The Air Force Weapons Laboratory (AFWL) requested the Aerospace Structures Information and Analysis Center (ASIAC) to provide the tools with which to recover the modal data from an aircraft structural model in a form suitable for input to VIBRA-6. The problem was addressed as ASIAC Problem 4.2-04, VIBRA/Ritz. Ritz is described in Section 6. The results of the work performed under that problem include:

1. A VAX/VMS version of the VIBRA-6 computer program, previously operational only on CDC and CRAY computer systems.
2. A NASTRAN aircraft model generation program with the capability of beam or plate aircraft model generation.
3. A NASTRAN postprocessor which creates VIBRA-6 AERO, IMOD, and LOAD fixed data decks from NASTRAN OUTPUT2 files and auxiliary files created by the model generation program.
4. Capability to recover mode shapes at NASTRAN aerodynamic points, and to pass these results to VIBRA-6.
5. Ability to perform the NASTRAN normal modes analysis using either standard eigenvalue methods or the Ritz procedure.
6. Interface to NASTPLOT for plotting structural and aerodynamic models.

This document summarizes the work performed under Problem 4.2-04 and the software produced. It provides examples of NASTRAN and VIBRA-6 analysis results obtained using the software.

## 2 OVERVIEW OF PROGRAM USAGE

Two computer programs have been generated to aid the user in going from aircraft geometric, section property, and material data to obtain VIBRA-6 analysis results. These programs are:

*CREATR*, used to create NASTRAN aircraft models, either beam models generated from section property data, or plate models generated from detailed geometric data. Beam models generated using *CREATR* can be linked directly to VIBRA-6 using *NAS2V6* and auxiliary files provided by *CREATR*. Plate models are created using a revised and expanded set of subroutines from the original ADAM code (Ref. 3).

*NAS2V6*, a program which reads NASTRAN OUTPUT2 files and auxiliary files generated by *CREATR*, and translates them into VIBRA-6 AERO, IMOD, and LOAD fixed data decks.

A VMS command file is provided to orchestrate the use of *CREATR*, NASTRAN, *NAS2V6*, *NASTPLOT*, and VIBRA-6, and to keep track of all files and file assignments necessary for their execution. The flow of execution is shown in Figure 1. The file naming convention and FORTRAN unit assignments are all handled by the command file. For reference, however, these file names are summarized in Table 1. FORTRAN unit assignments vary with the program being executed.

Upon executing this command file, the user is prompted for a Run ID. This Run ID will be used as the key to all subsequent file naming, as shown in Table 1. The only file naming restrictions that are made are on the input files for *CREATR*, *NAS2V6*, and VIBRA-6. In these cases, the input files must be named:

- \*\_CRE.INP for *CREATR* input
- \*\_N2V.INP for *NAS2V6* input
- \*\_RDD.DAT for the VIBRA-6 run data deck,

where the \* is the Run ID provided by the user. The command file also permits execution of all programs except NASTRAN and *NASTPLOT* in either an interactive or batch mode. (NASTRAN can only be executed in batch, and *NASTPLOT* can only be executed interactively). A history is kept of the analysis that was performed using the command file, and a synopsis of the history is provided on request.

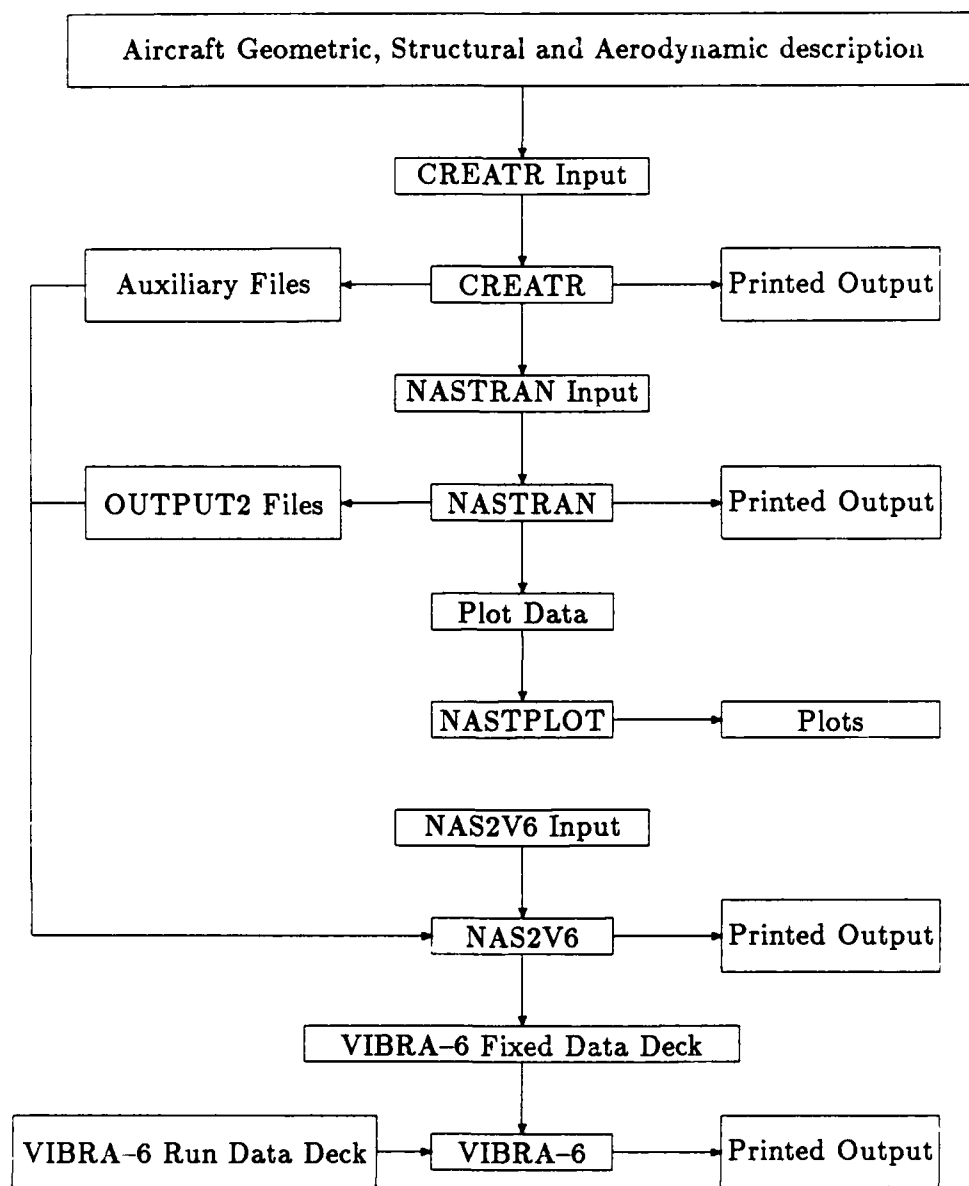


Figure 1. The CREATR—NASTRAN—VIBRA analysis loop.

File Name	description
RunID_AER.DAT	VIBRA-6 aerodynamic data file
RunID_ASY.NID	CREATR-generated NASTRAN input deck (Antisymmetric)
RunID_ASY.OUT	NASTRAN output file (Antisymmetric)
RunID_AUX.DAT	CREATR-generated auxiliary file
RunID_BGA.DAT	NASTRAN OUTPUT2 file BGPDT (Antisymmetric run)
RunID_BGS.DAT	NASTRAN OUTPUT2 file BGPDT (Symmetric run)
RunID_CRE.INP	User-supplied CREATR input file
RunID_CRE.OUT	CREATR output file
RunID_CSA.DAT	NASTRAN OUTPUT2 file CSTM (Antisymmetric run)
RunID_CSS.DAT	NASTRAN OUTPUT2 file CSTM (Symmetric run)
RunID_CTL.DAT	CREATR-generated control file
RunID_EQA.DAT	NASTRAN OUTPUT2 file EQEXIN (Antisymmetric run)
RunID_EQS.DAT	NASTRAN OUTPUT2 file EQEXIN (Symmetric run)
RunID_FDD.DAT	VIBRA-6 fixed data deck
RunID_FRS.DAT	VIBRA-6 frequency response data file
RunID_GUS.DAT	VIBRA-6 unit gust loads data file
RunID_HIS.DAT	History file documenting CREATR, NASTRAN, NAS2V6, NASTPLOT and VIBRA-6 runs
RunID_LAA.DAT	NASTRAN OUTPUT2 file LAMA (Antisymmetric run)
RunID_LAS.DAT	NASTRAN OUTPUT2 file LAMA (Symmetric run)
RunID_LDD.DAT	VIBRA-6 load data deck
RunID_LOD.DAT	VIBRA-6 unit load data deck
RunID_MGA.DAT	NASTRAN OUTPUT2 file of MGG diagonal (Antisymmetric run)
RunID_MGS.DAT	NASTRAN OUTPUT2 file of MGG diagonal (Symmetric run)
RunID_N2V.INP	User-supplied NAS2V6 input file
RunID_N2V.OUT	NAS2V6 output file
RunID_PHA.DAT	NASTRAN OUTPUT2 file PHIG (Antisymmetric run)
RunID_PHS.DAT	NASTRAN OUTPUT2 file PHIG (Symmetric run)
RunID_RDD.DAT	VIBRA-6 run data deck
RunID_SYM.NID	CREATR-generated NASTRAN input deck (Symmetric)
RunID_SYM.OUT	NASTRAN output file (Symmetric)
RunID_TRM.DAT	CREATR-generated (and user-editable) trim modes file
RunID_VIB.OUT	VIBRA-6 output file

**Table 1. File naming convention.**

### 3 USING CREATR

The user provides a single input file to CREATR describing the aircraft model to be generated. CREATR produces a NASTRAN input file for either Solution 3 (Normal Modes) or Solution 10 (Modal Flutter). If the user desires, CREATR will produce a set of auxiliary files that can be used with the results of the NASTRAN analysis to produce a VIBRA-6 fixed data deck. However, CREATR can be used simply as a NASTRAN aircraft model generation tool without considering VIBRA-6.

Aircraft can be idealized as beam or plate-type models using CREATR. If a beam structural model is used, an aerodynamic model can also be created and coupled to the structural model; a shortened version of NASTRAN Solution 10 (Modal Flutter) can then be used to produce the necessary modal data for the VIBRA-6 fixed data deck. At present, aerodynamic models cannot be coupled to plate-type structural models, nor can VIBRA-6 input data be generated for plate-type idealizations.

For plate-type modeling of aircraft, most of the original capabilities of the ADAM code have been retained in CREATR, and new capabilities have been added. CREATR input for plate-type models is essentially the same as ADAM input. A more detailed description of CREATR versus ADAM is provided in Section 3.2.

All programming in CREATR makes use of FORTRAN dynamic storage allocation to eliminate strict dimensional constraints. This approach was taken to be consistent with VIBRA-6, which imposes no hard dimensional limits on the aircraft modeler. In addition, all code which was adapted from existing code, such as ADAM, was converted to use dynamic storage allocation.

The input manual for CREATR is provided in Appendix A of this report.

#### 3.1 CREATING NASTRAN BEAM MODELS OF AIRCRAFT

The computer program ADAM was originally to be used as a baseline method of generating aircraft models to be linked to VIBRA-6 for vulnerability assessment. However, AFWL determined that the ADAM-type plate model was overly detailed for the level of analysis performed by VIBRA-6, and that structural details required for creation of a plate-type model would not normally be available to them. AFWL's primary interest in aircraft structural modeling was limited to beam-type representations. For these reasons, an aircraft beam model generation program was designed as a baseline with which to create both NASTRAN and VIBRA-6 input data.

The beam model generation part of CREATR simplifies input requirements for both NASTRAN and VIBRA-6, while eliminating the need to duplicate input between the two programs. It permits the modeler to generate a complete NASTRAN input deck without having to deal directly with NASTRAN documentation. It can also generate auxiliary files that can be linked together with NASTRAN output to form a complete VIBRA-6 fixed data deck.

The CREATR convention of user-supplied numbering of items like elements, grids, control surfaces and so on is common to almost all data sets. This approach was

taken for several reasons. First, the numbering helps users organize their input by permitting them to group items together (e.g., numbering all master elements on the wing with numbers 100 through 199). Second, items can be rearranged or removed without affecting other items in the group (i.e., just because element 1 was removed does not mean that the elements 2 through 99 have to be renumbered). This approach is similar to that taken by most finite element codes.

While a detailed description of CREATR input is provided in Appendix A, the following section gives a general discussion of the pertinent data sets used in creating beam models.

#### 3.1.1 Title, Control, and Dimensioning Information (Data Set 1.0)

The user provides a single title which is used for general identification and in the NASTRAN run. The user then specifies whether a beam or plate-type model will be created. Control information includes the type of NASTRAN solution run (normal modes, SOL 3, or modified modal flutter, SOL 10), how many modes to recover, whether to include alters for linking to VIBRA, where to provide NASTRAN SUPORT of the aircraft for rigid body modes, and whether to perform a symmetric or antisymmetric analysis (or both). In addition, the user provides flags to indicate whether to use the Ritz procedure, whether a plot file should be created, whether a VIBRA-6 load data deck should be created, and what kind of NASTRAN eigenvalue solution method should be used. For the Ritz procedure, the user can specify the types of gravity loads that are used to generate initial Ritz vectors. Dimensioning data that must be provided include counts of the number of tables, materials, master grids, and so on. Note that if the user requests a plot file to be made, the NASTRAN input deck for generating NASTPLOT plots is generated, together with appropriate plot set definitions. This deck may not be suitable for the actual NASTRAN analysis, and a separate nonplot CREATR run should be made before proceeding with an analysis.

#### 3.1.2 Table Input (Data Set 2.0)

Any number of tables are defined, each with a unique table number. Each table is simply a set of  $s$ - $G$  pairs, where the user is specifying some quantity  $G$  as a function of  $s$ .  $G$  could be Area,  $I_{11}$ , or any other element property which will be interpolated from the table. These properties are always element properties. Associated with each table is a table type, where the table type indicates how  $s$  is to be interpreted — is  $s$  in this table to be interpreted as a global  $x$  coordinate,  $y$  coordinate, and so on. The program determines the location of each element (or subelement) center  $xyz$  coordinate, then does the interpolation for each required property according to the table and table-type flagged for that property.

#### 3.1.3 Material Input (Data Set 4.0)

Any number of materials are defined by giving  $E$ ,  $G$ ,  $XNU$  and  $RHO$  values for each. Materials are given a unique material number by the user, so that the input order within the data set makes no difference.

#### 3.1.4 Master Grid and Element Definition (Data Sets 5.0 and 6.0)

Any number of master grids and elements are defined by the user. The number of NASTRAN elements to be created for each master element is specified. The table numbers to be used for interpolating area, inertia and nonstructural mass along the length of each master element are also specified. The component (wing, fuselage, etc.) to which each element belongs is specified. Master grid numbering is preserved — new NASTRAN grids are created between master grids as needed, in sequence starting with one higher than the highest master grid number.

#### 3.1.5 Control Surface Definition (Data Set 7.0)

Each control surface is given a number. Two master grids are used to define the control surface hinge line. The control surface is attached to the structural model at two other master grids. The component to which the control surface is attached and the type of control surface (symmetric or antisymmetric) are specified. The mass moment of inertia of the control surface about its hinge line and a hinge rotational stiffness are specified.

#### 3.1.6 Spring Connection Definition (Data Set 8.0)

Spring stiffnesses are specified between any master grids according to the aircraft axis system.

#### 3.1.7 Concentrated Mass Definition (Data Set 9.0)

The user can specify concentrated masses at any master grid, including translational and rotary inertia values.

#### 3.1.8 Rigid Connection Definition (Data Set 10.0)

The user can specify rigid connections between master grids in the model. The grids need not be coincident. The definition of rigid links follows the same approach used in NASTRAN (see the NASTRAN Theoretical Manual, Ref. 4), and CREATR will check to make sure that no master grid is dependent on more than one other grid's displacements. Dependent centerline grids with rigid links attached to them are subject to change when CREATR applies symmetric and antisymmetric boundary conditions. These CREATR-supplied changes will not affect the intended use of the rigid link, but will only avoid imposing boundary condition SPC's on dependent degrees of freedom (a fatal NASTRAN error).

#### 3.1.9 Aerodynamic Panel Definition (Data Set 11.0)

The user defines an aerodynamic panel for each planform and control surface by specifying the planform with four corner points. The number of chordwise and spanwise boxes for the panel must be provided, and the input requirements and approach to specifying nonuniform chordwise and spanwise box sizes are similar to VIBRA-6. It should be noted that the AERO model used to provide VIBRA-6 input will be different than one used to do a real aeroelastic analysis in NASTRAN. This problem arises because VIBRA-6 needs corner-type of points from which it interpolates across the

panel (to box centers) for its own analysis, whereas a stand-alone NASTRAN model would include the points at the box centers, but not the panel corners. Figure 2 illustrates the pseudopanel that CREATR generates and passes to NASTRAN when the user specifies that VIBRA-6 data are to be generated ( $KVIBRA \neq 0$  in Data Set 1.0).

#### 3.1.10 Aerodynamic Body Definition (Data Set 12.0)

The user can define slender and interference bodies for the aircraft by specifying the master grid end points and the number of body elements between them. The lengthwise breakdown of elements must be supplied. Radii and angular orientations for points on the body surfaces are specified. The input for aerodynamic bodies follows closely the analogous VIBRA-6 input, and a pseudobody is generated when the user specifies  $KVIBRA$  not equal to zero. This pseudobody is similar to the pseudopanel described above for the aerodynamic panel definition. Its purpose is to describe for NASTRAN a pseudobody with element centers at the actual endpoints of the real slender body. Figure 3 illustrates the pseudobody that CREATR generates and passes to NASTRAN when the user specifies that VIBRA-6 data are to be generated.

#### 3.1.11 Aero-Structural Model Spline Definition (Data Set 13.0)

All panels and bodies must be splined to structural elements, or NASTRAN will consider them to be fixed in space. The purpose of specifying splines is to tell NASTRAN and VIBRA-6 how to interpolate aerodynamic panel and body deflections from the deflections of structural elements. The user identifies the box and body element numbers within an aerodynamic element that are to be interpolated from a given master structural element.

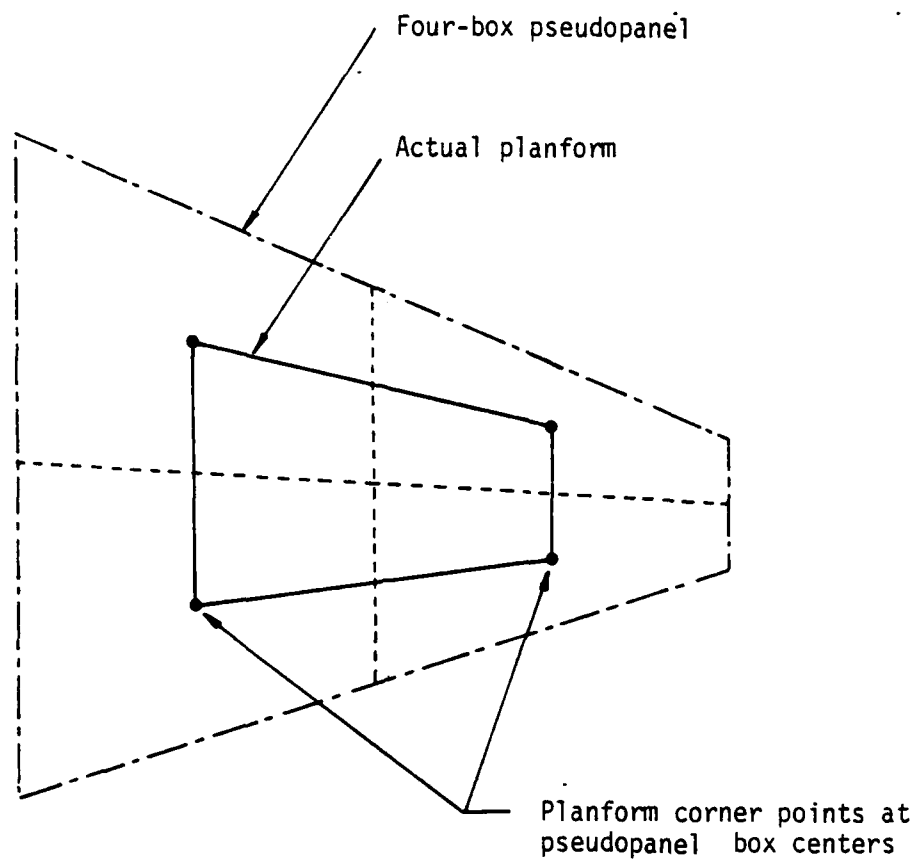
#### 3.1.12 VIBRA-6 Load Data Deck Definition (Data Set 14.0)

The CREATR input for the VIBRA-6 load data deck definition follows fairly closely the analogous VIBRA-6 input. One exception is that each CREATR master grid must be assigned to a single master element for purposes of assigning inertia loads. In addition, identification of boxes and body elements for pressure recovery is referenced to CREATR aerodynamic panel and body element numbers and their local box and element numbers, and the conversion to the VIBRA-6 convention is made internally.

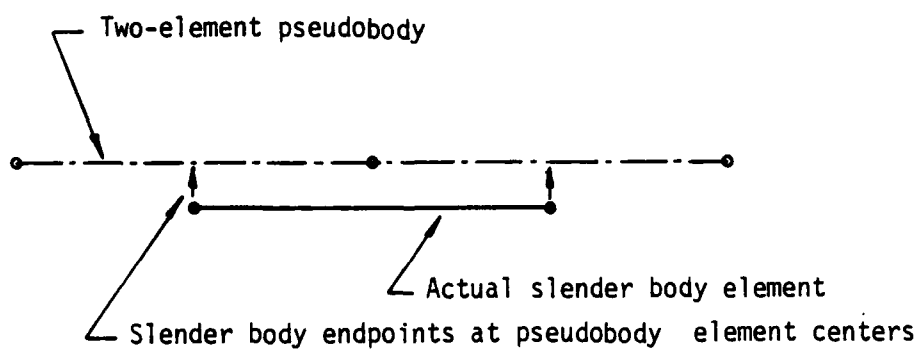
### 3.2 CREATING NASTRAN PLATE MODELS OF AIRCRAFT

The plate modeling concepts used in the CREATR code were adapted from the original ADAM code (Level 1.3) written by Hugh Griffis (Ref. 3). The internal coding bears little resemblance to ADAM, however, due to its conversion to dynamic storage allocation, and to the many changes made to it, including:

1. The explicit input of skin thickness for each section was eliminated. The original ADAM approach has been replaced by reference to a single table of constants. This change was made to eliminate the creation of multiple NASTRAN property cards (records) containing exactly the same values.



**Figure 2. CREATR-generated pseudopanel for NASTRAN.**



**Figure 3. CREATR-generated pseudobody for NASTRAN.**

2. An explicit user-supplied definition of common ribs, spars and surfaces between sections of the aircraft was incorporated. The original ADAM code eliminated duplicate grids between aircraft sections by examining their proximity in space — if they were close enough, they were combined into a single grid. This change was made to permit the user to connect airfoil sections to airfoil sections (as in a pylon connecting to a wing or a horizontal tail mounted on a vertical tail), and to allow for better control and tracking over the final grid numbering.
3. An echo of NASTRAN grids versus rib/angle, spar/frame and surface is provided so that the NASTRAN model and results can be traced back to the CREATR input.
4. Separate ADAM files for grids, properties, and so on have been removed. All NASTRAN data are written to a single file during creation. This change eliminated approximately seven scratch files which were kept open during ADAM execution.
5. NASTRAN input decks for both symmetric and antisymmetric boundary conditions are created in a single CREATR run. This eliminates the need for defining wing carry-through sections, or any boundary condition definition whatsoever for separate sections.
6. Definition of an ASET by ADAM was removed. Guyan reduction to the ASET is not necessary if the FEER method is used in COSMIC/NASTRAN.
7. Material properties are defined by reference to a material number defined in Data Set 4.0.
8. Bugs found during the course of the project were removed or identified, including:
  - Incorrect definition in original ADAM of PARAM WTMAS.
  - Complete SPC of all degrees of freedom of fuselage sections in original ADAM.
  - Incorrect index on loop over ribs in airfoil section definition caused the out-board set of CSHEARs to be missed.
  - Composite materials do not appear to work properly in the original ADAM, but this bug was not corrected.
9. All input data are read in at the beginning, echoed and checked extensively before creating the model.
10. All input data formats were changed to require six fields of 12 columns (as in VIBRA-6), some variable names were changed, the code was commented extensively, and statement numbers were changed to improve readability.

In spite of these changes, the geometry definition routines were used without change, the overall flow of the plate model definition portion of the code remains the same as ADAM, and essentially the same input is used. Note that the CREATR convention is to call wing-type sections airfoils, rather than wings, as is done in ADAM. Fuselage-type sections are always referred to as bodies.

Definition of plate-type models begins with input of Data Set 1.0, the same as for beam model definition. Then, instead of the table definitions provided in Data Set 2.0 for beam models, the user inputs a set of constant values (for such items as plate thicknesses) in Data Set 3.0. This input is followed by the same material property definition used for beam models. The input for plate models then moves to Data Set 15.0, which is essentially the same as the ADAM Group C input for wing section definition. The next data set, 16.0, defines body-type sections, and is essentially the same as ADAM Group B input for body sections. The final input for plate-type models is Data Set 17.0, which permits the user to connect the separate airfoil and body sections.

CREATR input data are detailed in Appendix A, but discussions of Data Sets 3.0, 15.0, 16.0 and 17.0 are provided in sections 3.2.1 through 3.2.4.

### 3.2.1 Constant Value Definition (Data Set 3.0)

This data set is provided so that plate thicknesses and bar areas (e.g., those on NASTRAN PQDMEM, PSHEAR, and PBAR cards or records) can be referenced by a constant number, rather than explicitly inputting floating point numbers for each section. In this way, a skin thickness of 0.375 can be assigned as constant number 1, and then this constant can be referred to for skins, ribs and so on, in any airfoil or body section.

### 3.2.2 Plate-type Airfoil Section Definition (Data Set 15.0)

The input for airfoil sections follows the ADAM Group C input fairly closely. The user must assign a unique number to each airfoil section. Figure 4 is taken from Ref. 3 to illustrate some of the geometric variables and the sign convention for input. Note that all skin thicknesses and rib/spar gauges are specified by reference to a constant number defined in Data Set 3.0. References to undefined constant numbers are detected by CREATR and summarized before termination of the run.

### 3.2.3 Plate-type Body Section Definition (Data Set 16.0)

The input for body sections follows the ADAM Group B input fairly closely. The user must assign a unique number to each body section. Figure 5 is taken from Ref. 3 to illustrate some of the geometric variables and the sign convention for input. Note that all skin thicknesses and frame/angle gauges are specified by reference to a constant number defined in Data Set 3.0. References to undefined constant numbers are detected by CREATR and summarized before termination of the run.

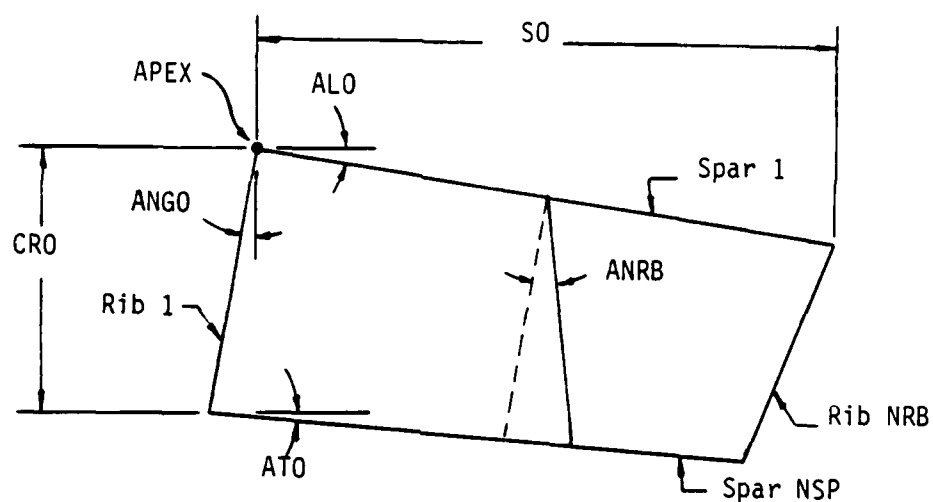


Figure 4. Airfoil section plate model variable definition.

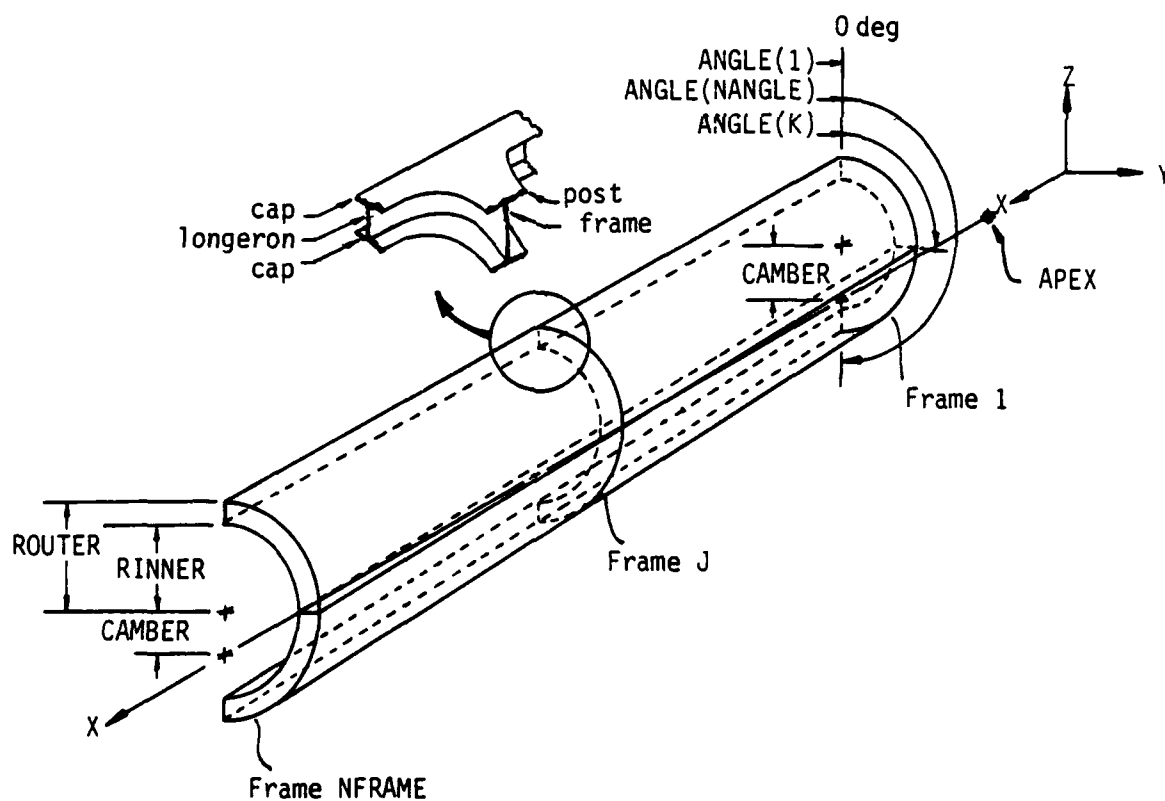
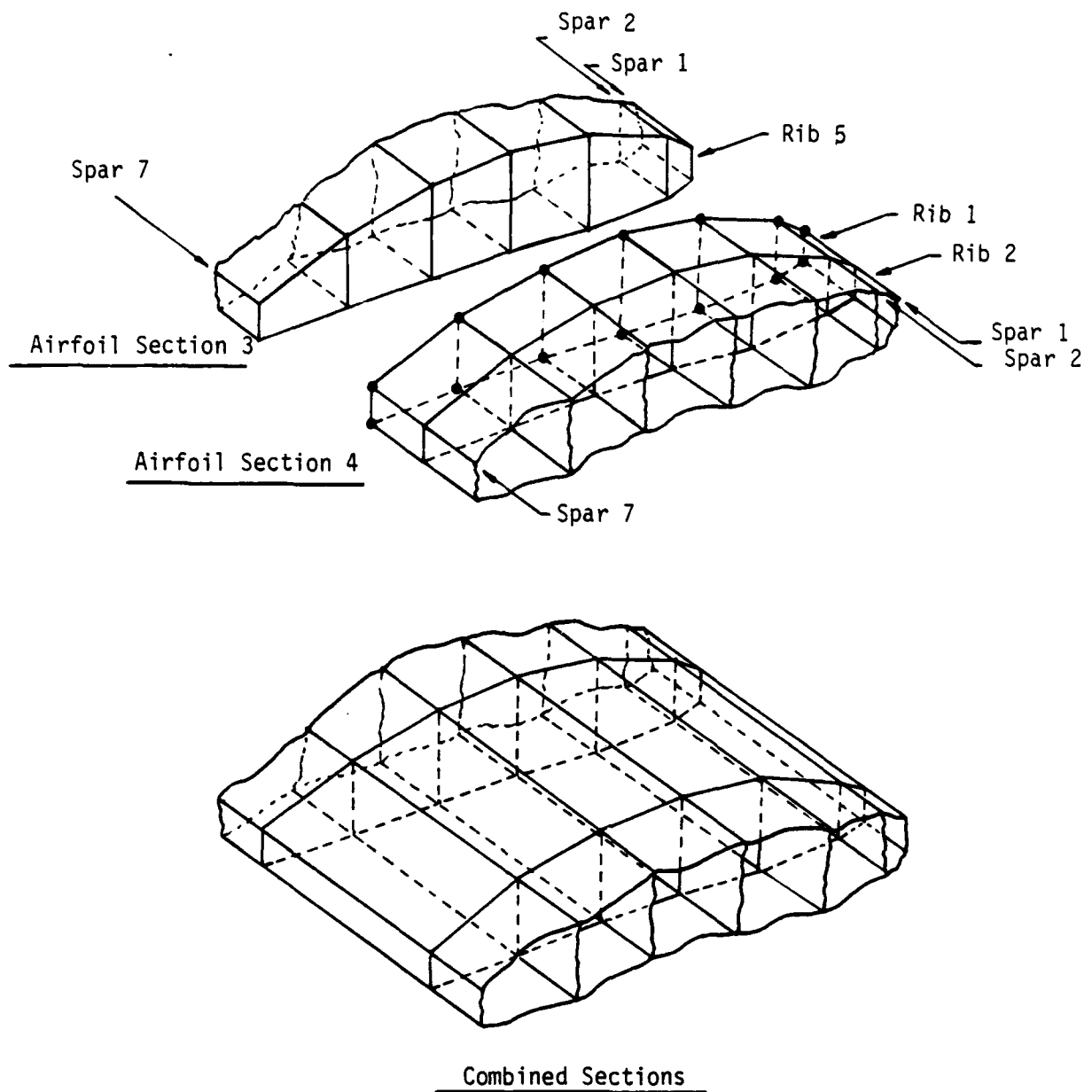


Figure 5. Body section plate model variable definition.

#### 3.2.4 Plate-type Section Connection Definition (Data Set 17.0)

All connections between sections must be defined in this data set. At a given connection, the set of grids belonging to one section will be retained in the model, and the set of grids that are equivalent to these grids in the connected section will be eliminated. Element connectivity and boundary conditions will be updated accordingly. The user specifies the airfoil or body numbers to be connected, and a range of ribs/frames or a range of spars/angles to be connected between the sections. Figure 5 shows an example of section connection and the corresponding Data Set 17.0 inputs. `CREATR` documents the actual NASTRAN grids which are retained and eliminated, and cross references them to section numbers, ribs/frames and spars/angles. Extensive input checks are provided to prevent retained grids in one connection from being eliminated in another.



Card Set 17.0 Input

3	5	1	0	5	7
4	1	1	0	1	7
3	5	1	1	5	7
4	1	1	1	1	7

**Figure 6. Connection definition between plate-type model sections.**

## 4 USING NAS2V6

NAS2V6 is the program used to translate data from NASTRAN to VIBRA-6. It takes NASTRAN OUTPUT2 files, together with auxiliary files generated during a CREATR run, and produces the complete VIBRA-6 fixed data deck. The load data deck is actually created directly by CREATR, and it is merely appended to the NAS2V6-generated AERO and IMOD files if the user so requests.

The NAS2V6 input manual is provided in Appendix B. The user-supplied input to NAS2V6 is quite small, containing only the information that is VIBRA-6 specific, such as reduced frequencies and mode identification. These types of inputs have no meaning for either CREATR or NASTRAN (SOL 3 or SOL 10), so they must be supplied directly to NAS2V6 by the user. In addition, VIBRA-6 print flags that are part of the fixed data deck are provided at this point. Due to its similarity to the VIBRA-6 input, a cross-reference is provided in the NAS2V6 input manual to the original AERO and IMOD deck group and card numbers.

NAS2V6 reads twelve NASTRAN OUTPUT2 files, one user-supplied input file, and three CREATR-generated auxiliary files. It produces a single VIBRA-6 fixed data deck and an output file documenting the input and creation process.

The user may modify or create from scratch a trim mode file to define the trim modes of the aircraft. CREATR automatically creates this ASCII file when control surfaces are defined in the input; however, there may be cases where the approach used in CREATR for defining control surfaces is inadequate. For example, if the entire horizontal tail or vertical tail rotates, the user must manually input the trim mode. Since a single aerodynamic panel will describe such a control surface, the trim mode is defined by providing the normal (or out-of-plane) displacements of the panel corner points for a one-radian rotation of the control surface. These values are usually simple for the user to calculate since they are equal to the normal distance of the panel corner points from the axis of rotation. Note that CREATR provides a list of the NASTRAN grid points that define the corners of all aerodynamic panels in the model and their xyz locations, and these are the grid numbers used in the trim mode file. A specific example of trim mode definition is provided in Section 7.1.3. The form and content of the trim mode file is given in Appendix C.

## 1 USING VIBRA-6 ON THE VAX

The VIBRA-6 computer program was originally written for execution on a CDC Cyber system employing a 60-bit word length. This version of VIBRA-6 was described in Ref. 1. At a later date, extensive changes were incorporated in the code, and it was converted to run on a CRAY computer with a 64-bit word, as described in Ref. 2. CDC-specific routines like READMS, WRITMS, and OPENMS were replaced by direct access file reads and writes in the CRAY version.

The initial problem to be solved in addressing this work was the conversion of the CRAY version of VIBRA-6 to a VAX version. The difficulties associated with the conversion process were numerous. After a complete VAX single precision version was assembled, it was discovered that numerical problems in the aerodynamic module were preventing a valid solution from being produced. This type of problem was not unexpected, but the magnitude of the single-to-double precision conversion task was quite high due to the dynamic storage allocation techniques used throughout the program. Nevertheless, the conversion process was completed, and the VAX double precision results are acceptably close to those obtained on the CRAY. Only the aerodynamic module and some portions of the frequency response module of VIBRA-6 were converted to double precision, since the other modules did not perform any operations requiring double precision.

The VAX version of VIBRA-6 resides in a single executable program. This program is produced by linking the object code from eleven separate modules described in the original VIBRA-6 documentation (Refs. 1 and 2). A separate executable could, in theory, be created for each module, but the VAX virtual memory operating system eliminates the need to do this. In fact, aside from some minor page faults which occur at program startup, the single-executable version should be almost exactly as efficient as would be multiple, smaller executables.

The CRAY version of VIBRA-6, due to its elimination of the CDC mass storage routines, READMS and WRITMS, used an inordinate amount of scratch disk space during execution (typically > 50 Mb) when converted directly to the VAX. This problem was caused by the organization of the direct access storage files inherited from the CRAY version. It was corrected by adopting an array to cross reference between direct access file record numbers and the actual occurrences of writes to the file. This modification reduced the required scratch storage to approximately 10 Mb for the samples examined.

## 6 THE RITZ PROCEDURE

The Ritz procedure, as implemented in COSMIC/NASTRAN, is documented in ASIAC report 685.1C (Ref. 5). For purposes of completeness, however, it will be reviewed briefly here.

Readers may be familiar with Rayleigh's method of determining an approximate value of the lowest structure natural frequency by using an assumed mode shape and deriving the Rayleigh quotient. The Ritz procedure begins with a similar approach, by choosing a load vector to be applied to the structure in order to generate an initial Ritz vector. Once the initial vector is defined, the Ritz procedure goes through a loop (formally, the Krylov sequence) to derive additional vectors which are mass orthonormalized. A transformation matrix is derived from a reduced eigenvalue problem to transform these vectors into the final mass and stiffness orthogonal Ritz vectors and to derive the approximate eigenvalues of the structure. The final Ritz vectors can then be used in a mode superposition analysis or as input to a VIBRA-6 vulnerability analysis.

Table 2 gives a synopsis of the Ritz procedure. The procedure is implemented in COSMIC/NASTRAN as a combination of DMAP alters for Solutions 3 and 10, and a user module, MODB. The user module, MODB, performs such operations as orthonormalization, appending and overwriting of vectors, and vector normalization. A listing of MODB and the DMAP alters for Solutions 3 and 10 are given in Ref. 5. The full source for these codes is provided on the distribution tape described in Appendix D.

- Given mass matrix  $\mathbf{M}$ , stiffness matrix  $\mathbf{K}$  and load vector  $\vec{p}$
- Triangularize  $\mathbf{K}$  such that  

$$\mathbf{K} = \mathbf{L}^T \mathbf{D} \mathbf{L}$$
- Solve for starting vector  $\vec{x}_1^*$   

$$\mathbf{K} \vec{x}_1^* = \vec{p}$$

$$\vec{x}_1^{*T} \mathbf{M} \vec{x}_1^* = 1$$
- Solve for additional vectors  $i = 2, \dots, L$ , orthonormalizing with respect to  $\mathbf{M}$   

$$\mathbf{K} \vec{x}_i^* = \mathbf{M} \vec{x}_{i-1}$$

$$c_j = \vec{x}_j^T \mathbf{M} \vec{x}_{i-1}^*, \text{ for } j = 1, \dots, i-1$$

$$\vec{x}_i^* = \vec{x}_i^* - \sum_{j=1}^{i-1} c_j \vec{x}_j^*$$

$$\vec{x}_i^{*T} \mathbf{M} \vec{x}_i^* = 1$$
- Form  $\mathbf{M}^*$  and  $\mathbf{K}^*$   

$$\mathbf{X} = [\vec{x}_1, \dots, \vec{x}_L]$$

$$\mathbf{M}^* = \mathbf{X}^T \mathbf{M} \mathbf{X}$$

$$\mathbf{K}^* = \mathbf{X}^T \mathbf{K} \mathbf{X}$$
- Solve the  $L$  by  $L$  eigenvalue problem  

$$[\mathbf{K}^* - \omega_i^2 \mathbf{M}^*] \vec{z}_i = 0$$

$$\mathbf{Z} = [\vec{z}_1, \dots, \vec{z}_L]$$
- Compute final Ritz vectors by orthogonalizing  $\mathbf{X}$  with respect to  $\mathbf{K}$   

$${}^0\mathbf{X} = \mathbf{X} \mathbf{Z}$$

Table 2. The Ritz Procedure.

## 7 SAMPLE PROBLEMS

The approach taken in addressing three sample problems, and the results obtained for those problems are provided in the following sections. The three sample problems include:

1. An analysis of the F/A-18 aircraft, including preparation of the model from tabular listings of structural properties, CREATR runs, NASTRAN runs, NAS2V6 runs, and VIBRA-6 runs. Comparisons are provided between Ritz and non-Ritz results.
2. A normal modes analysis of a plate-type model of an aircraft structure, including model creation using CREATR, and a comparison of results and execution times between the Ritz procedure and standard normal modes.
3. The original VIBRA-6 example problem, which is documented in Refs. 1 and 2, with comparisons between CRAY and VAX results.

Complete input and output for all computer runs are contained in the distribution tape described in Appendix D.

### 7.1 ANALYSIS OF THE F/A-18

The F/A-18 was selected by AFWL as a realistic test case of the capabilities of CREATR, NAS2V6, the Ritz procedure and the VAX version of VIBRA-6. All programs were exercised successfully, and the following discussion documents some of the practical aspects of performing such an analysis.

#### 7.1.1 Sources of Input Data

All input data for the model were obtained from McDonnell-Douglas Corporation report MDC A5773 (Ref. 6). Data contained in tables were input directly to the CREATR program. Inertia values were calculated from the tabulated EI and GJ values using standard values of E and G for aluminum. Structural areas were calculated from the tabulated linear weight properties using the density of aluminum. Note that detailed tabulations of structural properties versus position are input regard less of the detailing of the model itself; in this way, model refinement may be changed without ever modifying the tables themselves. Table inputs are the major part of the CREATR data.

As no information was available on allowable loads, order-of-magnitude estimates were made so as to permit a calculation of critical range to be made in the VIBRA-6 analysis.

Sections 7.1.2 through 7.1.4 describe the structural, aerodynamic and loads models. Some of the techniques and assumptions used in the modeling process are also described. Section 7.1.5 documents the analysis results using both the Ritz procedure to derive

normal modes and the standard NASTRAN eigenvalue solvers. The results of the VIBRA-6 analysis are summarized in Section 7.1.6.

Pertinent input, output, and auxiliary files used in this analysis are contained in the distribution tape described in Appendix D. Files for the F/A-18 which did not use the Ritz procedure begin with F18 followed by an underscore and additional file descriptors discussed in Section 2.0. Files for the F/A-18 which do use the Ritz procedure are also on the tape and begin with F18RTZ followed by an underscore and additional file descriptors. Although the discussion, figures, and tables that follow are fairly explicit, reference to the actual input data and results contained in these files may be required.

#### 7.1.2 Structural Model

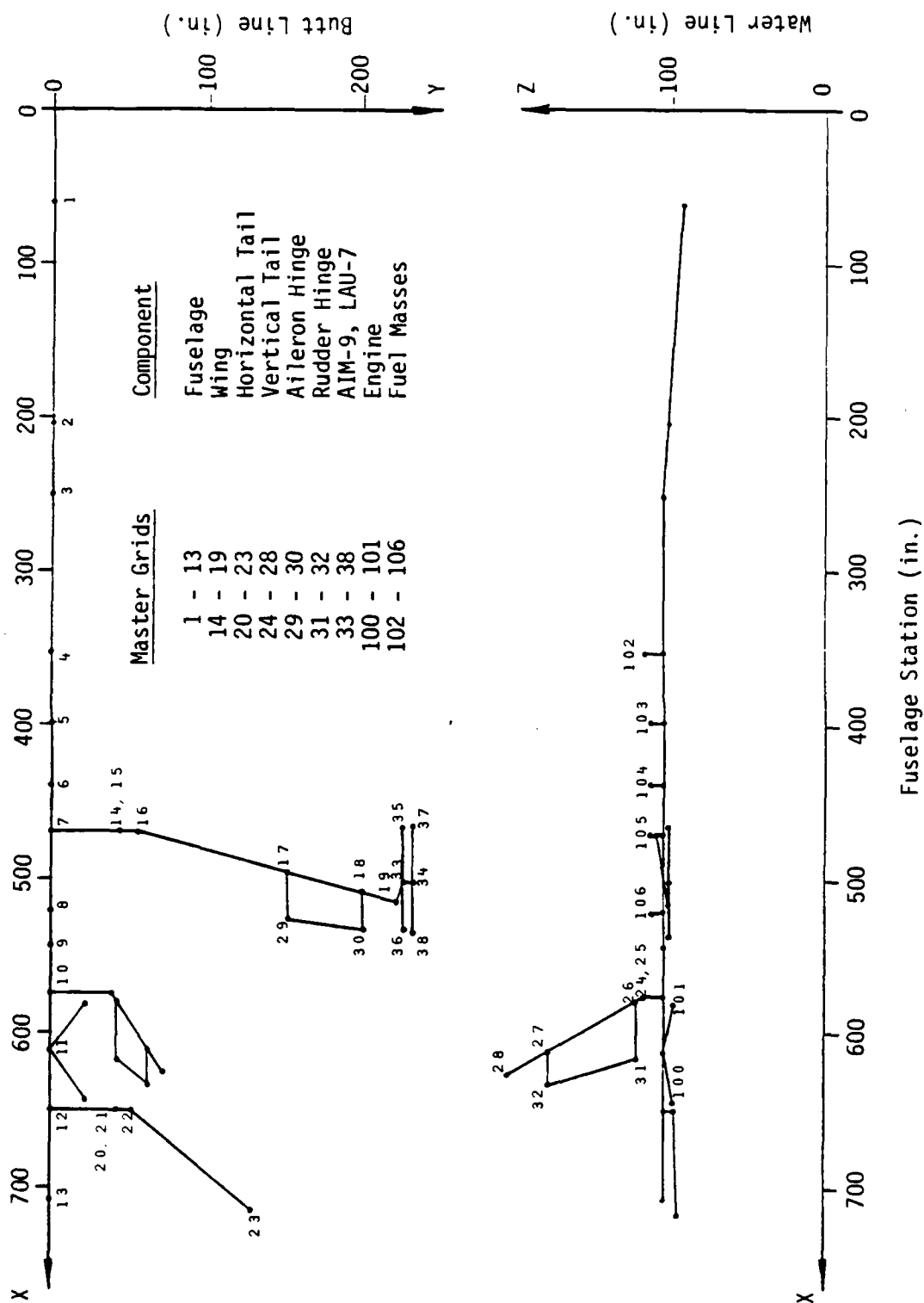
Figures 7 and 8 show the model of the aircraft as idealized for NASTRAN and VIBRA-6. Master grid numbers for the CREATR run are shown in Figure 7, and element numbers are indicated in Figure 8. Note that the master elements are subdivided into one or more subelements for the actual analysis, so the master grids need only be defined at key points, such as end points, component connection points, concentrated mass locations, and control surface connection locations. Control surface hinge lines and their (rigid) connection to the aircraft are also shown in the figure. In the F/A-18 model illustrated, 45 master grids and 26 master elements are used to define a total of 82 actual structural grids, 61 bar elements, 11 spring elements, and 23 rigid elements.

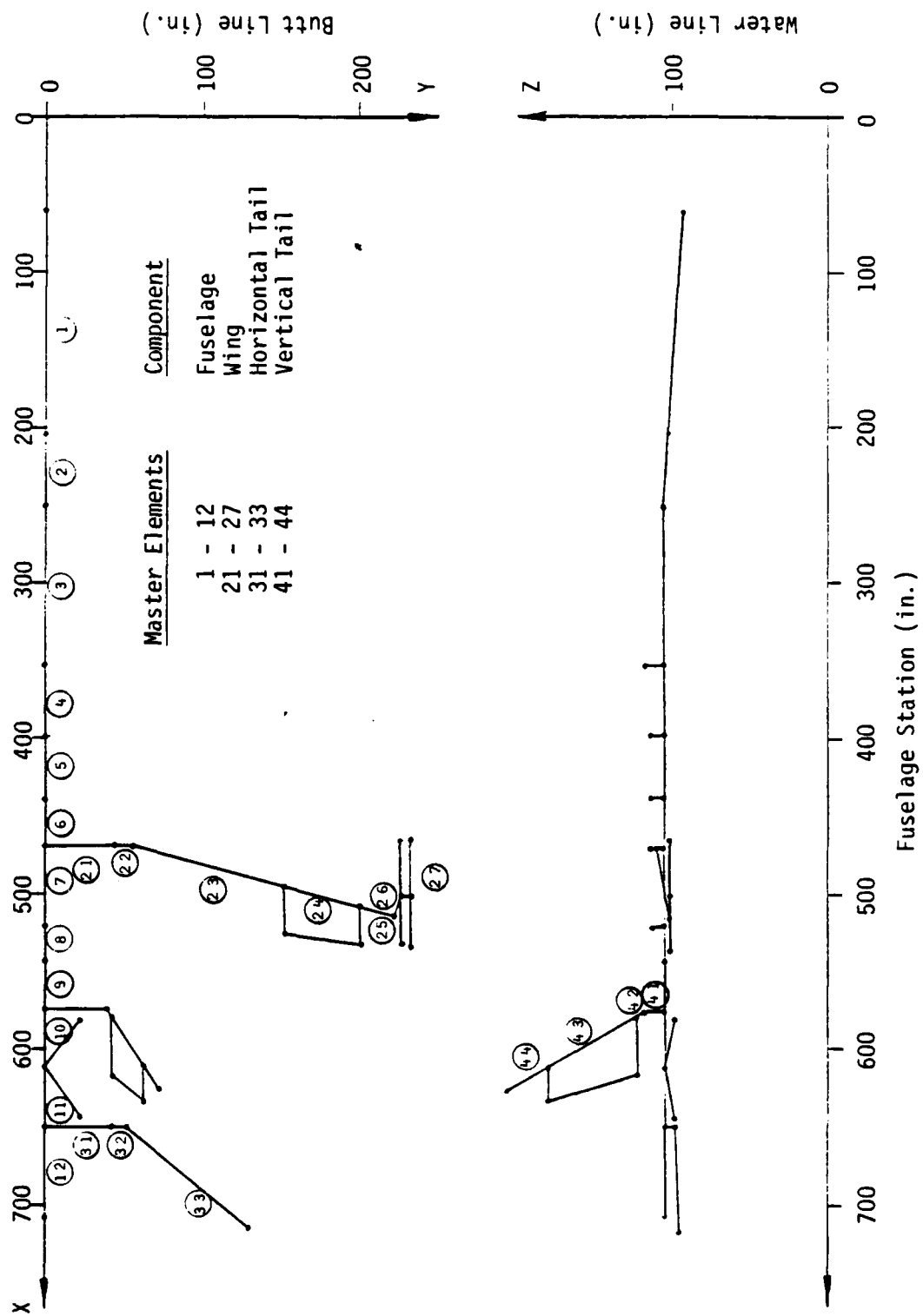
Tables 3 through 6 give the full structural properties of the aircraft. Concentrated masses used in the model are given in Tables 7 and 8. Fuselage (and any other centerline member) properties must be input with half values to CREATR, and the necessary translation to full centerline masses required by VIBRA-6 is handled automatically by NAS2V6 later. Properties for the individual model elements are interpolated from these tables. Full concentrated mass values are given in Tables 7 and 8. Concentrated masses with large inertia values should be modeled as dumbbell masses. In the case of the engine, for example, the total weight of 2,206 lb was assigned to grids approximately 30 inches apart to simulate the engine pitch and yaw inertia properly. These two grids were then connected via rigid links to a single independent fuselage point. In addition, two engine grids are required in the VIBRA-6 load data deck to define the direction of engine thrust.

Note that the model used here is intended for the prediction of gross structural response of the aircraft to gust effects of a nuclear blast. Model refinement is in accordance with the intended mode of use.

#### 7.1.3 Aerodynamic Model

The aerodynamic model for the aircraft is shown in Figure 9. Four panels are used to model the wing, one from the wing root to the inboard edge of the aileron, two across the chord at the aileron, and one outboard of the aileron. Ten boxes are used across the chord for the full wing span. Box edges must line up between the wing panels. A single panel is used to model the horizontal tail. Note that streamwise boxes are not required to align between the wing and the horizontal tail due to nonalignment of the





## Mass Properties

Section from (B.L.)	Wing Weight (lb/in)					
	TORQ BOX	LNCH/MSL	FUEL	TE/CS	LE/CS	TOTAL
43.35- 56.00	23.744	0.000	6.909	1.807	0.000	32.460
56.00- 76.00	8.049	0.000	6.425	0.922	0.813	16.209
76.00- 96.00	11.798	0.000	5.750	0.687	1.145	19.380
116.00-136.00	6.181	0.000	3.605	0.828	0.605	11.219
136.00-154.00	5.621	0.000	1.569	0.543	0.539	8.272
154.00-158.50	10.631	0.000	1.569	0.633	0.540	13.373
158.50-164.75	10.631	0.000	0.000	0.633	0.540	11.804
164.75-172.00	10.631	0.000	0.000	0.633	0.455	11.719
172.00-190.00	9.881	0.000	0.000	0.472	0.756	11.109
190.00-201.75	2.145	0.000	0.000	0.434	0.359	2.939
201.75-207.00	2.145	0.000	0.000	0.000	0.359	2.504
207.00-222.50	3.524	0.000	0.000	0.000	0.328	3.852
222.50-225.50	3.524	0.000	0.000	0.000	0.000	3.524
225.50-231.25	0.000	15.130	0.000	0.000	0.000	15.130
231.25-236.25	0.000	38.960	0.000	0.000	0.000	38.960

## Stiffness Properties (Local along elastic axis)

Stiffness contribution of LE and TE control surfaces is neglected in the current model.

B.L. (in)	EI (lb in <sup>2</sup> )	GJ (lb in <sup>2</sup> )
43.35	7200.E6	6500.E6
64.00	7200.E6	6500.E6
76.00	5400.E6	5600.E6
87.00	5400.E6	4800.E6
100.00	4200.E6	3500.E6
100.10	3200.E6	2800.E6
120.00	2200.E6	2000.E6
140.00	1400.E6	1400.E6
140.10	1100.E6	1100.E6
160.00	620.E6	620.E6
180.00	280.E6	350.E6
200.00	150.E6	180.E6
220.00	100.E6	125.E6
240.00	72.E6	88.E6

Table 3. F/A-18 Wing properties.

### Mass Properties

Section from (B.L.)	Horizontal Tail Weight (lb/in)
41.92- 53.91	5.775
53.91- 65.91	3.075
65.91- 77.90	1.483
77.90- 89.89	0.983
89.89-101.88	0.767
101.88-113.88	0.650
113.88-121.87	0.625
121.87-129.87	0.675

### Stiffness Properties (Local along elastic axis)

B.L. (in)	EI (lb in <sup>2</sup> )	GJ (lb in <sup>2</sup> )
49.92	940.E6	720.E6
56.91	720.E6	530.E6
61.91	540.E6	420.E6
71.90	260.E6	260.E6
81.90	130.E6	155.E6
91.89	68.E6	92.E6
101.88	34.E6	52.E6
112.92	17.E6	26.E6
121.87	11.E6	8.E6
130.00	4.E6	4.E6

Table 4. F/A-18 Horizontal tail properties.

### Mass Properties

Section from (W.L.)	Vertical Tail Weight (lb/in)		
	TAIL	RUDDER	TOTAL
118.38-120.59	5.226	0.000	5.226
120.59-134.35	5.226	0.815	6.041
134.35-149.39	2.709	0.259	2.968
149.39-164.42	1.969	0.211	2.180
164.42-179.46	1.516	0.198	1.714
179.46-191.21	1.979	0.000	1.979
191.21-199.67	1.542	0.000	1.542
199.67-209.21	0.786	0.000	0.786

### Stiffness Properties (Local along elastic axis)

Stiffness contribution of the rudder is neglected in the current model.

W.L. (in)	EI (lb in <sup>2</sup> )	GJ (lb in <sup>2</sup> )
118.38	1850.E6	1150.E6
127.78	1310.E6	960.E6
137.17	920.E6	740.E6
146.57	640.E6	520.E6
155.97	410.E6	340.E6
165.36	245.E6	205.E6
174.76	145.E6	120.E6
184.16	82.E6	68.E6
193.56	43.E6	35.E6
202.95	20.E6	15.E6
209.21	12.E6	10.E6

Table 5. F/A-18 Vertical tail properties.

## Mass Properties

Section from (F.S.)	Fuselage Weight (lb/in)		
	STRUCTURE	LE EXT	TOTAL
60.50-129.50	2.125	0.000	2.125
129.50-204.50	24.667	0.000	24.667
204.50-286.50	25.841	0.537	26.378
286.50-383.00	19.606	2.404	22.010
383.00-453.00	27.443	0.000	27.443
453.00-488.00	47.914	0.000	47.914
488.00-557.50	42.475	0.000	42.475
557.50-615.00	18.626	0.000	18.626
615.00-709.50	11.757	0.000	11.757

## Stiffness Properties (Local along elastic axis)

F.S. (in)	EI-vertical (lb in <sup>2</sup> )	EI-lateral (lb in <sup>2</sup> )	GJ (lb in <sup>2</sup> )
0.00	0.E9	0.E9	0.E9
10.00	1.4E9	1.2E9	3.2E9
20.00	1.1E9	0.9E9	3.0E9
40.00	1.4E9	1.6E9	4.0E9
85.00	2.0E9	2.2E9	5.8E9
110.00	2.0E9	2.2E9	5.8E9
129.50	5.6E9	5.8E9	8.5E9
150.00	5.6E9	8.5E9	8.5E9
180.00	10.E9	18.E9	8.5E9
210.00	16.E9	21.E9	3.4E9
250.00	32.E9	26.E9	4.1E9
270.00	45.E9	30.E9	5.2E9
310.00	60.E9	44.E9	9.0E9
360.00	130.E9	64.E9	32.E9
400.00	140.E9	68.E9	37.E9
430.00	140.E9	185.E9	65.E9
510.00	140.E9	210.E9	78.E9
540.00	56.E9	160.E9	80.E9
570.00	45.E9	115.E9	80.E9
600.00	45.E9	125.E9	160.E9
625.00	45.E9	140.E9	150.E9
710.00	45.E9	140.E9	150.E9

Table 6. F/A-18 Fuselage properties.

RT SIDE ENGINE (X=612.60, Y=22.00, Z=98.50)

Weight= 2206. lb

I-pitch = 2359960. lb in<sup>2</sup>

I-roll = 271000. lb in<sup>2</sup>

I-yaw = 2272100. lb in<sup>2</sup>

LAU-7 (X=500.51, Y=229.00, Z=112.66)

Weight= 87. lb

I-pitch = 89500. lb in<sup>2</sup>

I-roll = 240. lb in<sup>2</sup>

AIM-9 (X=501.88, Y=233.75, Z=112.66)

Weight= 195. lb

I-pitch = 224400. lb in<sup>2</sup>

I-roll = 1810. lb in<sup>2</sup>

**Table 7. F/A-18 Concentrated mass/inertia properties.**

TANK 1 (X=352.60, Y=0.00, Z=119.00)

Weight= 2767. lb

I-pitch =1447600. lb in<sup>2</sup>

I-roll = 684700. lb in<sup>2</sup>

I-yaw =1454800. lb in<sup>2</sup>

TANK 2 (X=398.50, Y=0.00, Z=112.90)

Weight= 1681. lb

I-pitch =427000. lb in<sup>2</sup>

I-roll =506000. lb in<sup>2</sup>

I-yaw =315000. lb in<sup>2</sup>

TANK 3 (X=438.00, Y=0.00, Z=111.80)

Weight= 1420. lb

I-pitch =339000. lb in<sup>2</sup>

I-roll =384000. lb in<sup>2</sup>

I-yaw =270000. lb in<sup>2</sup>

TANK 4 (X=471.50, Y=0.00, Z=112.30)

Weight= 1580. lb

I-pitch =386000. lb in<sup>2</sup>

I-roll =479000. lb in<sup>2</sup>

I-yaw =353000. lb in<sup>2</sup>

TANK 5 (X=520.70, Y=0.00, Z=112.90)

Weight= 2035. lb

I-pitch =934000. lb in<sup>2</sup>

I-roll =457000. lb in<sup>2</sup>

I-yaw =947000. lb in<sup>2</sup>

Table 8. F/A-18 Concentrated fuel mass/inertia properties.

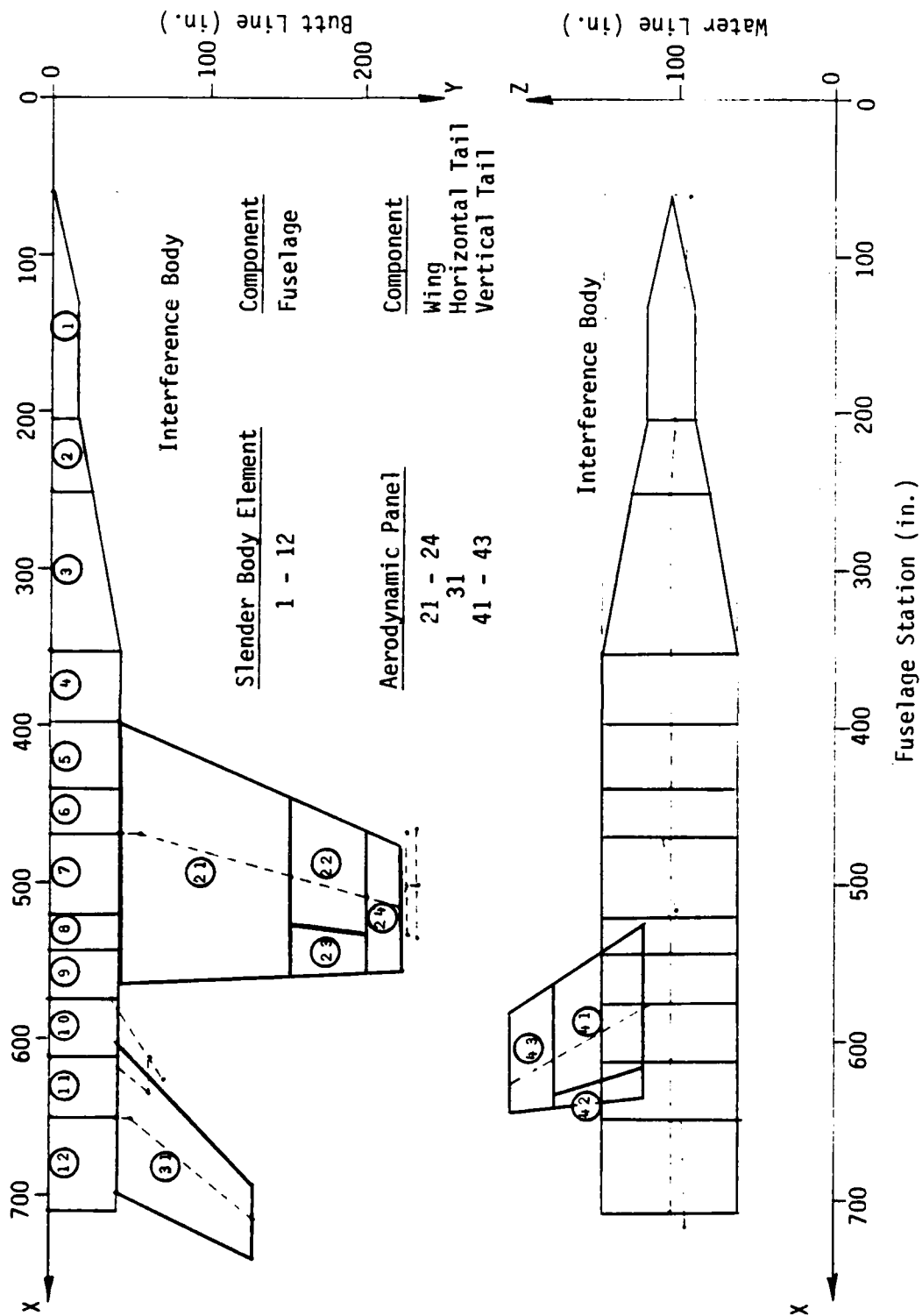


Figure 9. F/A-18 Aerodynamic model.

planforms themselves. Three panels are used to model the vertical tail (right side only), two across the chord at the rudder, and one across the chord outboard of the rudder to the tip. Box sizes must be determined in accordance with the guidelines provided for VIBRA-6 in specific, and doublet lattice theory in general (Ref. 2, Pt 1, p 176).

The master structural element breakdown of the fuselage in this case dictates the refinement of the aerodynamic body modeling of the fuselage. The refinement of the fuselage structural model was itself dictated by the existence of five fuel tanks and the engines along its length, modeled as concentrated masses. To make input easier, the displacement of a single aerodynamic body element is defined by, at most, one master element via the spline input. Since there are nine master elements along the fuselage, there had to be at least nine aerodynamic body elements. In turn, each of the aero body elements must contain at least two slender body elements and one interference element. This modeling is overly refined for the fuselage, but is required to simplify input requirements at the front end. A less refined aero model of the body could have been created by specifying the aero body element grids that are to be interpolated from specific master elements. Six angular locations for the interference body were chosen.

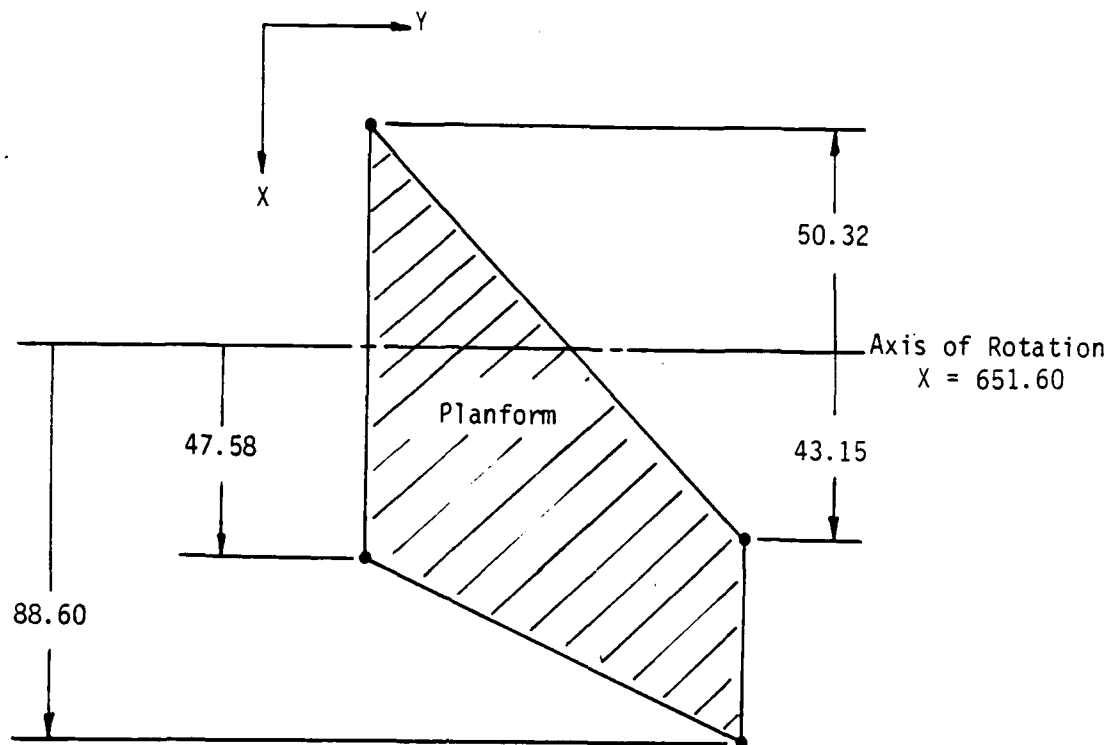
Some liberties must be taken with the idealization of the aerodynamic model to make box edges line up with the interference body surface at connection points. In the case of the model shown, the inboard edges of the horizontal and vertical tails were moved slightly to eliminate any gaps. In addition, as shown in Figure 9, the aerodynamic body aspect ratio was assumed to be 1.0 to simplify the input. The influence of this simplification could be investigated using VIBRA-6.

Roll and yaw trim modes are defined using the control surfaces for the model; however, the pitch trim mode, which is accomplished through rotation of the entire horizontal tail, must be added manually to the trim mode file, according to the format shown in Appendix C. In this case, an entire aerodynamic panel rotates about some arbitrary line in space, and the trim mode is defined in the trim mode file by specifying the out-of-plane displacement of the panel corner points. Figure 10 illustrates the approach. NAS2V6 reads the trim mode file and expands it to the form required for input to VIBRA-6.

#### 7.1.4 Loads Model

To recover a critical range from the VIBRA-6 program, an aircraft loads model must be defined via a load data deck. VIBRA-6 imposes few restrictions on the loads model, and it need not be very refined to recover, say, wing root bending moments. The VIBRA-6 load model is defined using CREATR by taking advantage of the aircraft master grid and element definition. If loads are desired at a certain point, the modeler should provide a master grid near the location. This practice will be followed quite naturally in almost all instances, since loads at connection points will usually be of most interest. The loads model for the F/A-18 is not shown in a separate figure as it corresponds exactly to the structural model defined using master elements.

A cross-reference must be provided between each master grid and the master element to which its inertia loading shall be applied. This inconvenience is necessary to



### CREATR Output

Panel No 31

NASTRAN AERO GRIDS FROM 166 to 169

	INBOARD EDGE		OUTBOARD EDGE	
	LEADING GRID 166	TRAILING GRID 167	LEADING GRID 168	TRAILING GRID 169
X	0.60128E+03	0.69918E+03	0.69475E+03	0.74020E+03
Y	0.43240E+02	0.43240E+02	0.12987E+03	0.12987E+03
Z	0.99240E+02	0.99240E+02	0.96250E+02	0.96250E+02

### Trim Mode File Input

1	
166	-50.32
167	47.58
168	43.15
169	88.60

Figure 10. Defining a trim mode.

to avoid the inertia load from a single grid contributing to the integrated loads more than once. Most master grids will lie at an intersection of two or more elements, and it is the modeler's responsibility to assign only one beam to each grid in the loads model. The impact of the assignment will be negligible in the case of moments at the grid location, but will affect the integrated shear loadings at the grid location for the different beams. In addition, master grids defining control surface hinge lines must be assigned to master elements, as do any master grids that are connected via rigid links to some other grid. Grids which are generated by CREATR between master grids are assigned to beams in the loads model according to user-supplied spline input for the aero model.

Integrated loads can be recovered at any location. For the F/A-18 example, only loads at the wing, horizontal tail and vertical tail root were requested, together with one point on the fuselage, at the wing root connection. Familiarity with VIBRA-6 integrated load sign conventions and numbering are required, and the fact that loads may be dependent on the grid numbering sequence should be recognized. If for some reason, master elements were defined from the wing tip toward the root, the beam load definition would be different than if they were numbered from the root to the tip. This convention is internal to VIBRA-6, and so is carried through in CREATR.

#### 7.1.5 Normal Modes Solution

The COSMIC/NASTRAN normal modes solution is described for both standard NASTRAN eigensolvers and for the Ritz procedure. The lower twenty or so eigenvalues and eigenvectors are almost identical between the Ritz procedure and the Givens method in COSMIC/NASTRAN.

The FEER method is the preferred technique offered by COSMIC/NASTRAN to extract natural frequencies and mode shapes, especially when the number of modes to be recovered is small in comparison to the total structural degrees of freedom, and where the frequency range of the modes of interest is not known *a priori*. Also, the structure mass matrix can be singular for the FEER method solution. For the F/A-18 aircraft model, however, the FEER method experienced numerical problems in tridiagonalization of the mass matrix, causing the analysis to abort. To circumvent this problem, the Givens method was employed to extract natural modes and frequencies up to 75 Hertz. (Twenty to twenty-four modes were recovered. A higher level of refinement would be required to obtain meaningful modes beyond this point. In addition, the Ritz procedure eventually exhausts the trial space, and no more independent mode shapes can be derived from the original static load vectors shortly beyond this point.)

The theoretical background for the Ritz procedure is provided in a separate document (Ref. 5), and was briefly reviewed in Section 6.0. Suffice it to say that the Ritz procedure permits fast extraction of approximate eigenvectors and eigenvalues based on an initial static displacement vector. Any structural modes which are orthogonal to the load vector used to derive this initial static displacement vector are automatically excluded from the solution, so natural modes that do not contribute in the dynamic forced response analysis are eliminated. Moreover, the Ritz modes themselves have

been found to be a more efficient basis for predicting dynamic response than are the true natural modes of the structure (Refs. 7 and 8).

The eigenvalues and eigenvectors derived using the Ritz procedure can change as the number of Ritz vectors which are solved for is increased. As a rule of thumb, at least two more Ritz vectors should be derived than are used in the subsequent forced response analysis. For example, if  $L$  vectors are desired for the forced response analysis,  $L+2$  Ritz vectors should be recovered. If  $L+3$  were recovered instead, there would be little difference in the first  $L$  eigenvalues and vectors; however, if only  $L$  vectors were recovered, the last few of them would be significantly different from those obtained when  $L+2$  were recovered. This rule of thumb is suggested based on a series of simple test cases, and not any rigorous proof.

For the F/A-18 model, two orthogonal gravity (inertia) loads were used to obtain the initial static displacement vectors for the Ritz procedure. Gravity loads in the global Y (lateral) and global Z (vertical) directions were used, so excitation of modes orthogonal to these load conditions was avoided (e.g., fuselage axial modes will not appear). Results are given in Tables 9 and 10, and the corresponding natural frequencies found in the Givens solution are also provided for comparison.

#### 7.1.6 VIBRA-6 Analysis

The VIBRA-6 analysis was carried out in four separate runs, using the following run data decks:

- A — AERO run only
- B — UNIT gust loads run
- C — FRSP and GUST run
- D — BLST run for critical range

The run data decks are referred to in this manner because they are labeled with a A, B and so on extension on the distribution tape described in Appendix D. The analyses generate voluminous output, which is included for reference on the distribution tape; however, for documentation here, only the results of the blast run will be discussed.

Results were obtained using both standard normal modes and Ritz modes. All modes below 30 Hertz were used for the analyses. Critical range results, shown in Table 11 are the same between the two runs. Note that the values of allowable bending moments are only order-of-magnitude estimates, so the quantitative critical range result is not meaningful, although the comparison between the two sets of normal modes is of use. Plots of the load time history at the V-tail root are also provided as Figure 11 for comparison.

All analyses were executed on a VAX 11/750 with a floating point accelerator (FP750). The AERO run took approximately five hours of CPU time, and the other three runs combined took approximately one and one-half hours.

## 7.2 BUILDING AN AIRCRAFT PLATE MODEL USING CREATR

The aircraft model chosen for a test of the plate model building capability of CREATR was the same as supplied with the original ADAM code. Since the input

SYMMETRIC MODES			
Mode	Ritz Frequency (Hz)	Givens Frequency (Hz)	
1	0	0	(Fore-aft rigid body)
2	0	0	(Plunge rigid body)
3	0	0	(Pitch rigid body)
4	3.363119E+00	3.363119E+00	
5	7.624109E+00	7.624105E+00	
6	8.086273E+00	8.085778E+00	
7	1.152047E+01	1.152025E+01	
8	1.190343E+01	1.190326E+01	
9	1.309958E+01	1.309953E+01	
10	1.456934E+01	1.456911E+01	
11	1.792154E+01	1.791994E+01	
12	1.816751E+01	1.816215E+01	
13	2.904748E+01	2.904723E+01	
14	3.062889E+01	3.059179E+01	
15	3.369447E+01	3.368734E+01	
16	4.539601E+01	4.531865E+01	
17	4.880421E+01	4.878115E+01	
18	5.405917E+01	5.385881E+01	
19	6.595360E+01	6.092399E+01	
20	6.954782E+01	6.469651E+01	

Table 9. F/A-18 Symmetric mode frequencies.

ANTISYMMETRIC MODES			
Mode	Ritz Frequency (Hz)	Givens Frequency (Hz)	
1	0	0	(Lateral rigid body)
2	0	0	(Roll rigid body)
3	0	0	(Yaw rigid body)
4	6.557380E+00	6.557200E+00	
5	7.199058E+00	7.198692E+00	
6	7.701903E+00	7.701875E+00	
7	1.108685E+01	1.108685E+01	
8	1.249016E+01	1.249016E+01	
9	1.424453E+01	1.424452E+01	
10	1.582334E+01	1.582331E+01	
11	2.020777E+01	2.020414E+01	
12	2.060114E+01	2.058346E+01	
13	2.945079E+01	2.945072E+01	
14	3.513504E+01	3.504179E+01	
15	3.703720E+01	3.697705E+01	
16	4.628609E+01	4.607973E+01	
17	5.141068E+01	5.096899E+01	
18	5.579179E+01	5.506032E+01	
19	6.608266E+01	6.253852E+01	
20	6.887489E+01	6.380196E+01	
21	9.519506E+01	6.500571E+01	
22	1.055377E+02	6.733178E+01	
23	1.314647E+02	7.009903E+01	
24	1.986745E+02	7.355373E+01	

Table 10. F/A-18 Antisymmetric mode frequencies.

MAXIMUM LOADS

STA	TIME	R SIDE+	TIME	R SIDE-	TIME	L SIDE+	TIME	L SIDE-	MAX+	MAX-
1	0.0260	0.1161E+8	0.0500	-0.93387E+7	0.0260	0.1161E+8	0.0500	-0.93387E+7	0.20000E+8	-0.20000E+8
2	0.0650	0.46395E+8	0.0300	-0.61819E+8	0.0650	0.15382E+7	0.0275	-0.10047E+7	0.90000E+7	-0.90000E+7
3	0.1000	0.53588E+8	0.1475	-0.33237E+8	0.0275	0.57780E+8	0.0550	-0.71015E+8	0.10000E+7	-0.10000E+7
4	0.0325	0.32839E+7	0.0100	-0.18763E+7	0.0275	0.32851E+7	0.0325	-0.29768E+7	0.33000E+7	-0.33000E+7

LOADCH PKMAX= 0.99548E+8 0.99548E+8 0.90176E+8

ORIENTATION NO. 13

MATERIAL VELOCITY= 197.9884FPS  
 MAX ALLOWABLE VELOCITY= 198.6873FPS  
 P AMBIENT= 14.1727 PSI  
 OVERPRESSURE= 3.9235 PSI  
 MAX ALLOW. OVERPRESSURE= 3.9432 PSI

MAXIMUM POS. AND NEG. LOAD RATIOS

STA	LOAD	TIME
4	0.9955	0.7625
4	0.9018	0.0325

COORDINATES OF AIRCRAFT AND BURST AT TIME= -1.5899 SECS  
 AIRCRAFT (EFAS)  
 BURST (EFAS)  
 X = 0.15046E+4  
 Y = 0.00000E+0  
 Z = 0.10000E+4

DISTANCE BURST TO AIRCRAFT AT INTERCEPT  
 SLNTR0 = 0.29212E+4 FT.

DISTANCE BURST TO AIRCRAFT NOW IS  
 SLNTRG = 0.32869E+4 FT.  
 XE-XB = 0.15046E+4 FT.  
 YE-YB = 0.29212E+4 FT.  
 ZE-ZB = 0.00000E+0 FT.

CONVERGED SOLUTION  
 3 ITERATIONS  
 CRITICAL RANGE IS 2921.17FT.

(a) Range results using standard NASTRAN normal modes.

Table 11. Comparison of Ritz and non-Ritz VIBRA-6 range results.

MAXIMUM LOADS

STA	TIME	R SIDE+	TIME	R SIDE-	TIME	L SIDE+	TIME	L SIDE-	MAX+	MAX-
1	0.0250	0.1160E+0	0.0500	-0.9381E+7	0.0250	0.1160E+0	0.0500	-0.9381E+7	0.2000E+8	-0.2000E+8
2	0.0650	0.4660E+0	0.0300	-0.6118E+6	0.0650	0.1641E+7	0.0275	-0.1070E+7	0.9000E+7	-0.9000E+7
3	0.0625	0.6406E+0	0.1475	-0.3380E+0	0.0275	0.6808E+0	0.0650	-0.7121E+0	0.1600E+7	-0.1600E+7
4	0.0325	0.3251E+7	0.0100	-0.1932E+7	0.7825	0.3285E+7	0.0325	-0.3031E+7	0.3300E+7	-0.3300E+7
LOADCH PKMAX=		0.9966E+0		0.9966E+0		0.9186E+0				

ORIENTATION NO. 13

MATERIAL VELOCITY= 197.7146FPS  
 MAX ALLOWABLE VELOCITY= 198.6024FPS  
 P AMBIENT= 14.1727 PSI  
 OVERPRESSURE= 3.9219 PSI  
 MAX ALLOW. OVERPRESSURE= 3.9413 PSI

MAXIMUM POS. AND NEG. LOAD RATIOS

STA	LOAD	TIME
4	0.9955	0.7825
4	0.9186	0.0325

COORDINATES OF AIRCRAFT AND BURST AT TIME = -1.5907 SECS

AIRCRAFT (EFAS)	BURST (EFAS)
X = 0.1505E+4	X = 0.0000E+0
Y = 0.0000E+0	Y = -0.2922E+4
Z = 0.1000E+4	Z = 0.1000E+4

DISTANCE BURST TO AIRCRAFT AT INTERCEPT

SLNTR0 = 0.2922E+4 FT.

DISTANCE BURST TO AIRCRAFT NOW IS

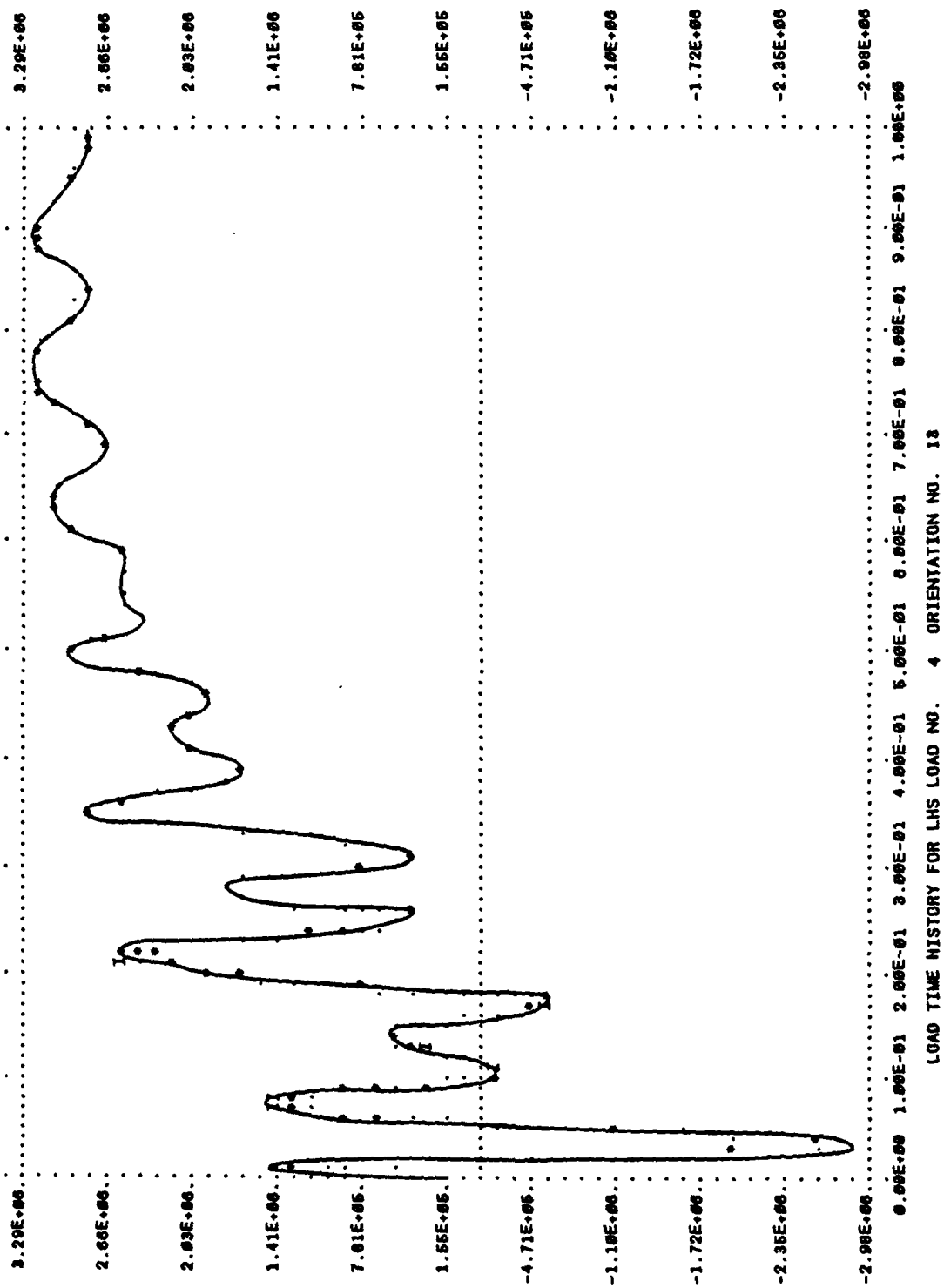
SLNTRG = 0.3287E+4 FT.
XE-XB = 0.1505E+4 FT.
YE-YB = 0.2922E+4 FT.
ZE-ZB = 0.0000E+0 FT.

CONVERGED SOLUTION

3 ITERATIONS  
 CRITICAL RANGE IS 2922.20FT.

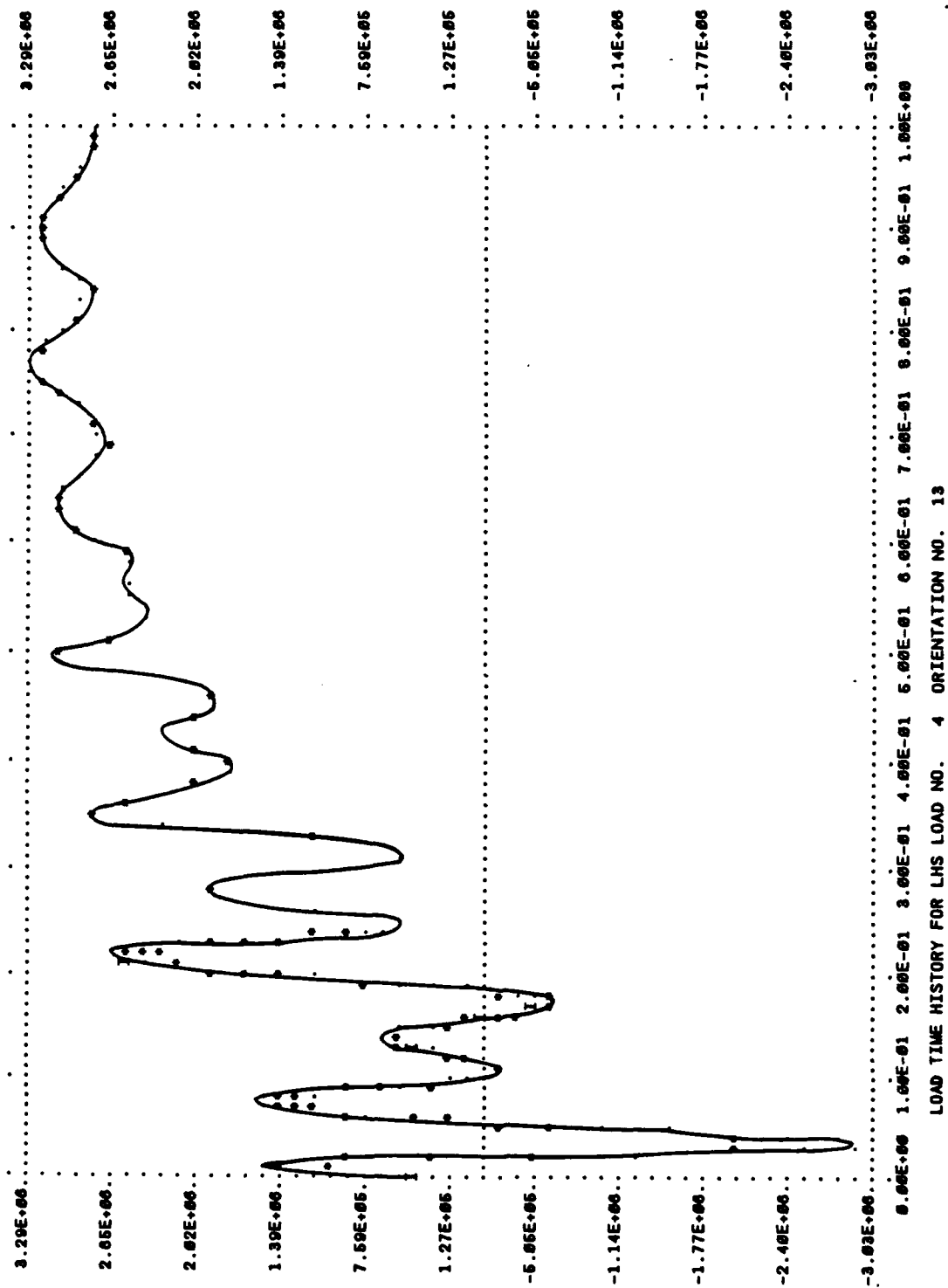
(b) Range results using Ritz modes.

Table 11. (Concluded.)



(a) Load history results using standard NASTRAN normal modes.

Figure 11. Comparison of Ritz and non-Ritz V-tail root load time history results.



(b) Load history results using Ritz modes.

Figure 11. (Concluded.)

is essentially the same between ADAM and the CREATR plate-type model, only formatting changes and some additional input were required. The major change in input was the section connection definition (Data Set 17.0), defining the way in which the individual airfoil and body sections are connected together.

The aircraft is defined as thirteen individual airfoil sections for the wing, horizontal tail and vertical tail, and a single body section for the fuselage. All plate thicknesses are provided in the constant definition data set (Data Set 3.0). Airfoil and body skins are modeled as membrane (CQDMEM) elements; spars, frames, angles and frames are modeled as shear (CSHEAR) elements, with bars (PBAR) representing caps. Note that all coordinates are referenced to an apex point, whose position is shown in Figure 4 for airfoils and Figure 5 for bodies.

The section connection definition input (Data Set 17.0) was discussed in Section 3.2. To connect a wing to the fuselage, the modeler might specify "eliminate the grids in body section I, from frame J to frame K on the outer surface, and replace them with the grids in airfoil section L, from rib M to rib N on the upper surface." An example of section connection definition was provided in Figure 6.

Note that CREATR checks the user-supplied connections to prevent a previously eliminated grid from being identified as retained in another connection. Such an input is not a fatal error — CREATR simply issues a warning and replaces the grid reference with the correct one from the retained section. This means that the user need not be overly careful to identify a single retained grid at a connection point, which is a helpful feature, especially when more than two sections connect at a single point. The NASTRAN grids that are retained and eliminated are always listed in the CREATR output. All common boundaries on connecting surfaces must be identified in order to properly connect together the individual sections. Particularly for complex models, this input must be carefully thought out and prepared.

NASTRAN normal modes (Sol 3) analyses were made of the aircraft generated using CREATR. A comparison of the normal modes results and run times between the FEER method (Ref. 4) and the Ritz procedure (Ref. 5) is provided in Tables 12 and 13 for the symmetric and antisymmetric runs respectively. The time savings and accuracy of the Ritz procedure is apparent from the results of these tables.

### 7.3 COMPARISON OF VAX AND CRAY VERSIONS OF VIBRA-6

A discussion of the conversion of CRAY VIBRA-6 to VAX VIBRA-6 was provided in Section 5. This section documents the differences in results between the new VAX version and the original CRAY version. The model used for comparison was that discussed in Refs. 1 and 2. The aircraft is a twin engine transport; the aerodynamic model (taken from Ref. 2) is shown in Figure 12. Note that the results documented in Ref. 2 were extensive, but not a complete listing. A microfiche copy of the complete analysis results from the CRAY version was supplied to ASIAC by Mr. Gerald M. Campbell of AFWL/NTAT, and those results are used for the comparison.

Table 14 shows a comparison between the VAX and CRAY critical range results

SYMMETRIC MODES			
Mode	Ritz Frequency (Hz)	FEER Frequency (Hz)	
1	0	0	(Fore-aft rigid body)
2	0	0	(Plunge rigid body)
3	0	0	(Pitch rigid body)
4	7.88	7.88	
5	23.57	23.57	
6	27.85	27.84	
7	30.55	30.54	
8	32.28	32.24	
9	60.79	60.65	

	Ritz Procedure	FEER Method
Total CPU time	13,008 s	18,841 s
Eigenvalue Extraction time	3,337 s	9,121 s

**Table 12. Plate model symmetric modes and run times.**

ANTISYMMETRIC MODES			
Mode	Ritz Frequency (Hz)	FEER Frequency (Hz)	
1	0	0	(Lateral rigid body)
2	0	0	(Roll rigid body)
3	0	0	(Yaw rigid body)
4	9.76	9.75	
5	24.18	24.18	
6	28.74	28.71	
7	30.75	30.74	
8	35.03	34.81	
9	38.77	38.50	

	Ritz Procedure	FEER Method
Total CPU time	11,145 s	18,476 s
Eigenvalue Extraction time	3,085 s	8,864 s

**Table 13. Plate model antisymmetric modes and run times.**

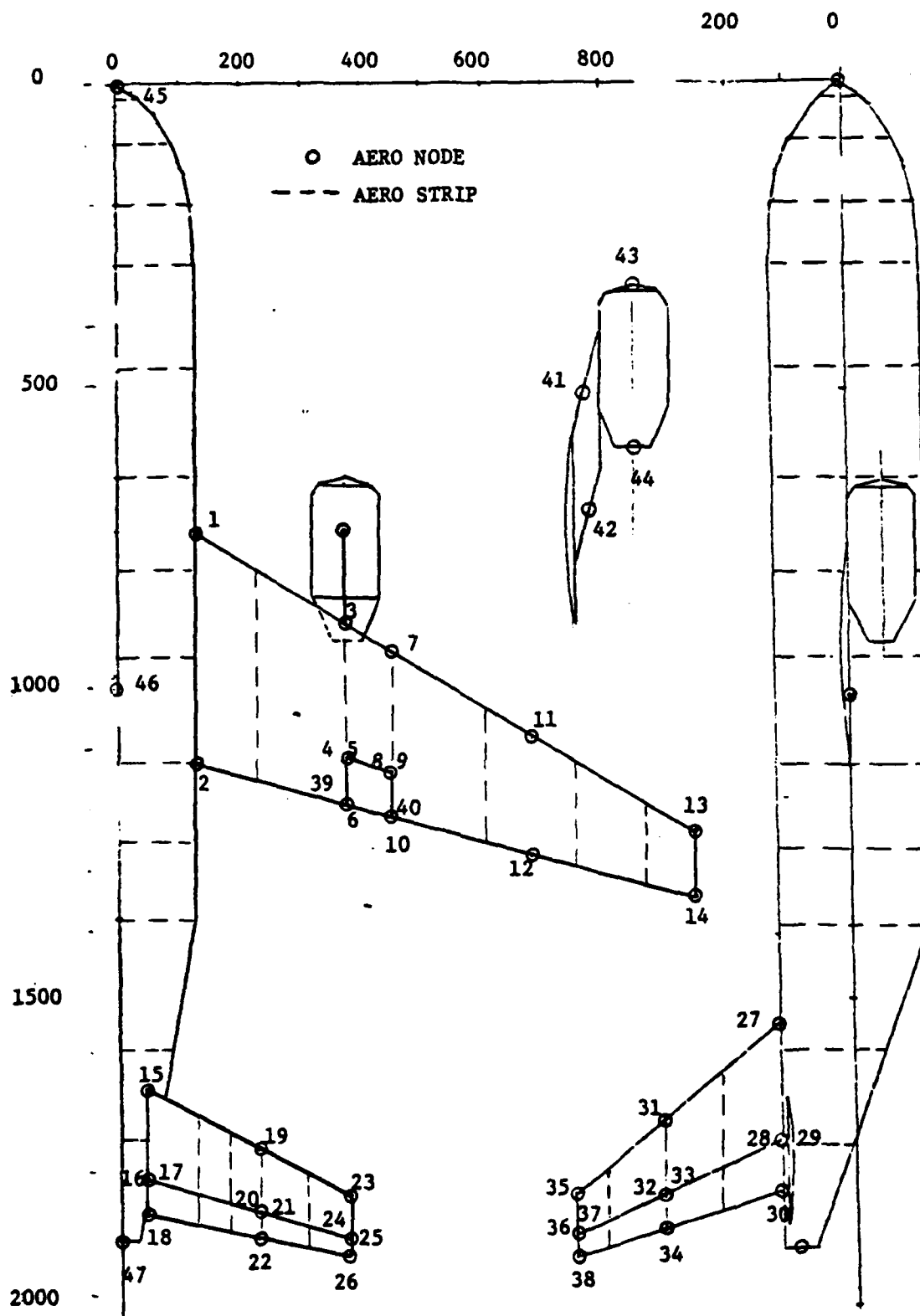


Figure 12. Aerodynamic model of transport aircraft.

MAXIMUM LOADS											
STA	TIME	R SIDE+	TIME	R SIDE-	TIME	L SIDE+	TIME	L SIDE-	MAX+	MAX-	
1	0.4280	0.19122E+6	0.2040	-0.17968E+6	0.4280	0.19122E+6	0.2040	-0.17968E+6	0.50000E+6	-0.50000E+6	
2	0.4780	0.10389E+9	0.1780	-0.92352E+8	0.4780	0.10389E+9	0.1780	-0.92352E+8	0.22000E+9	-0.22000E+9	
3	0.2400	0.18275E+6	0.3880	-0.11188E+6	0.2400	0.18275E+6	0.3880	-0.11188E+6	0.40000E+7	-0.40000E+7	
4	0.4680	0.32450E+6	0.1540	-0.28314E+6	0.4680	0.32450E+6	0.1540	-0.28314E+6	0.40000E+7	-0.40000E+7	
5	0.2440	0.53518E+5	0.0980	-0.74724E+5	0.2440	0.53518E+5	0.0980	-0.74724E+5	0.80000E+5	-0.80000E+5	
6	0.9980	0.00000E+0	0.0000	0.00000E+0	0.9980	0.00000E+0	0.0000	0.00000E+0	0.50000E+5	-0.50000E+5	
7	0.4680	0.16018E+6	0.1880	-0.17988E+6	0.4680	0.16018E+6	0.1880	-0.17988E+6	0.20000E+6	-0.20000E+6	
8	0.4880	0.19003E+6	0.1640	-0.14149E+6	0.4880	0.19003E+6	0.1640	-0.14149E+6	0.20000E+6	-0.20000E+6	
9	0.0120	0.13490E+6	0.1580	-0.14066E+6	0.0120	0.13490E+6	0.1580	-0.14066E+6	0.10000E+7	-0.10000E+7	
10	0.9980	0.00000E+0	0.0000	0.00000E+0	0.9980	0.00000E+0	0.0000	0.00000E+0	0.10000E+11	-0.10000E+11	
LOADCH	PKMAX=	0.98016E+0	0.98016E+0	0.93405E+0							

ORIENTATION NO. 6

MATERIAL VELOCITY= 58.9987FPS  
 MAX ALLOWABLE VELOCITY= 58.1529FPS  
 P AMBIENT= 14.1727 PSI  
 OVERPRESSURE= 1.0482 PSI  
 MAX ALLOW. OVERPRESSURE= 1.0701 PSI

MAXIMUM POS. AND NEG. LOAD RATIOS

STA	LOAD	TIME
8	0.9802	0.4880
5	0.9341	0.0980

COORDINATES OF AIRCRAFT AND BURST AT TIME = -5.3352 SECS  
 AIRCRAFT (EFAS)  
 X = 0.50489E+4  
 Y = 0.00000E+0  
 Z = 0.10000E+4  
 BURST (EFAS)  
 X = 0.00000E+0  
 Y = 0.00000E+0  
 Z = 0.83844E+4

DISTANCE BURST TO AIRCRAFT AT INTERCEPT  
 SLNTR0 = 0.73644E+4 FT.

DISTANCE BURST TO AIRCRAFT NOW IS  
 SLNTRG = 0.89289E+4 FT.  
 XE-XB = 0.50489E+4 FT.  
 YE-YB = 0.00000E+0 FT.  
 ZE-ZB = -0.73644E+4 FT.

CONVERGED SOLUTION  
 3 ITERATIONS  
 CRITICAL RANGE IS 7364.37FT.

(a) Range results using VAX VIBRA-6.

Table 14. Comparison of VAX and CRAY VIBRA-6 range results.

MAXIMUM LOADS

STA	TIME	R SIDE+	TIME	R SIDE-	TIME	L SIDE+	TIME	L SIDE-	MAX+	MAX-
1	.4300	.1700E+6	.2140	-0.1600E+6	.4300	.1700E+6	.2140	-0.1600E+6	0.5000E+6	-0.5000E+6
2	.4800	.10324E+9	.1700	-0.01219E+8	.4800	.10324E+9	.1700	-0.01219E+8	0.22000E+9	-0.20000E+9
3	.2400	.18452E+6	.3700	-0.11925E+6	.2400	.18452E+6	.3700	-0.11925E+6	0.40000E+7	-0.40000E+7
4	.4700	.32970E+6	.1540	-0.24875E+6	.4700	.32970E+6	.1540	-0.24875E+6	0.40000E+7	-0.40000E+7
5	.2400	.49014E+6	.0940	-0.70319E+6	.2400	.49014E+6	.0940	-0.70319E+6	0.00000E+5	-0.80000E+5
6	1.0000	.8000E+6	.0000	-0.00000E+0	1.0000	.8000E+6	.0000	-0.00000E+0	0.50000E+5	-0.50000E+5
7	.4700	.15794E+6	.1800	-0.14225E+6	.4700	.15794E+6	.1800	-0.14225E+6	0.20000E+6	-0.20000E+6
8	.4900	.19004E+6	.1420	-0.12318E+6	.4900	.19004E+6	.1420	-0.12318E+6	0.20000E+6	-0.20000E+6
9	.0140	.12920E+6	.1540	-0.13765E+6	.0140	.12920E+6	.1540	-0.13765E+6	0.10000E+7	-0.10000E+7
10	1.0000	.00000E+0	.0000	-0.00000E+0	1.0000	.00000E+0	.0000	-0.00000E+0	0.1000E+11	-0.1000E+11

LOADCH PKMAX= 0.98020E+6

ORIENTATION NO. 6

MATERIAL VELOCITY= 52.9285FPS  
 MAX ALLOWABLE VELOCITY= 53.9894FPS  
 P AMBIENT= 14.1727PSI  
 OVERPRESSURE= 0.9711PSI  
 MAX ALLOW. OVERPRESSURE= 0.9913PSI

MAXIMUM POS. AND NEG. LOAD RATIOS

STA	LOAD	TIME
8	0.9882	.4900
5	0.8790	.0900

COORDINATES OF AIRCRAFT AND BURST AT TIME = -6.7204 SECS

AIRCRAFT (EFAS)	BURST (EFAS)
X = 0.54211E+4	X = 0.00000E+0
Y = 0.00000E+0	Y = 0.00000E+0
Z = 0.10000E+4	Z = 0.00186E+4

DISTANCE BURST TO AIRCRAFT AT INTERCEPT  
 SLNTR0 = 0.78198E+4 FT.

DISTANCE BURST TO AIRCRAFT NOW IS

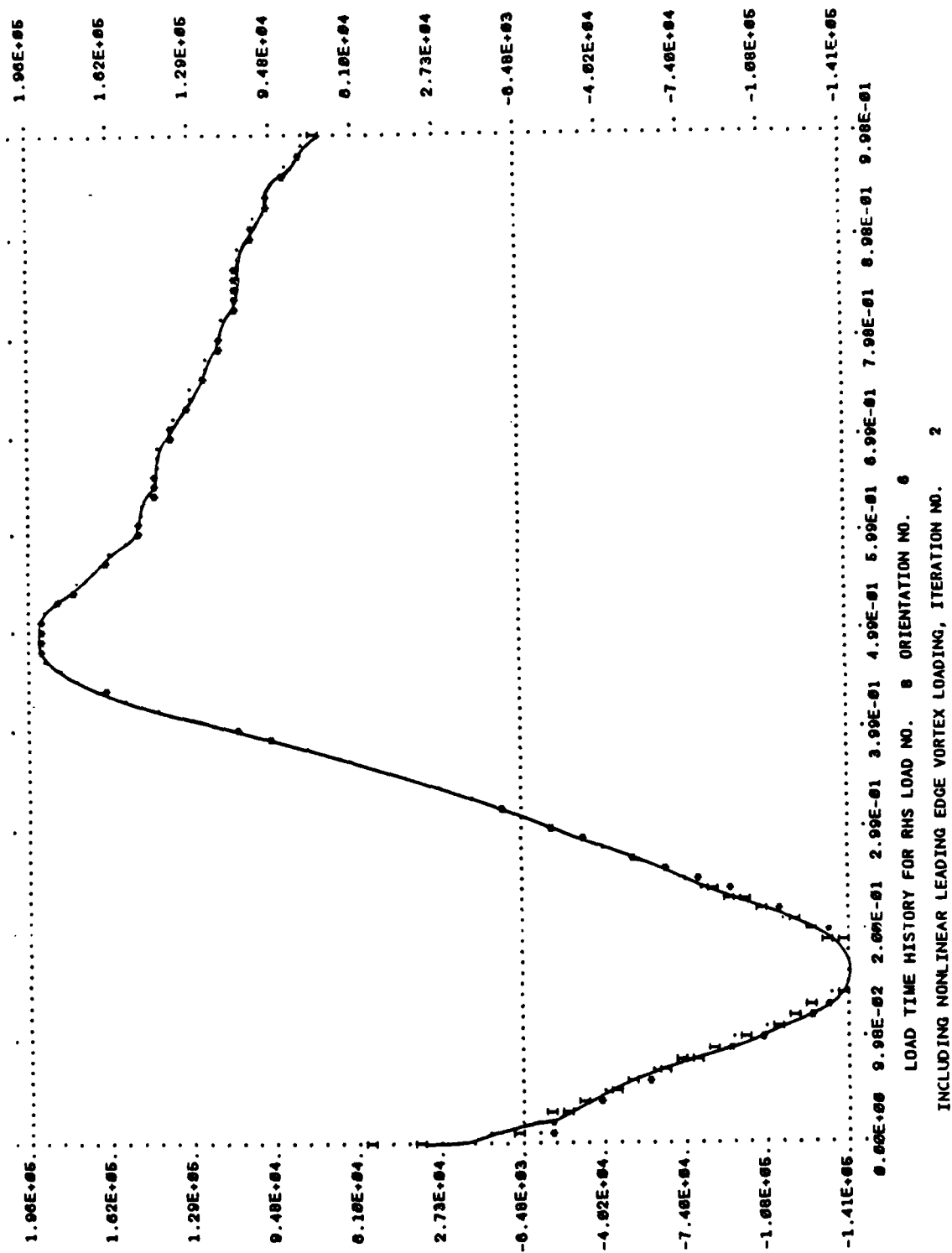
SLNTRG	XE-XB	YE-YB	ZE-ZB
0.96149E+4 FT.	0.54211E+4 FT.	0.00000E+0 FT.	-0.78198E+4 FT.

CONVERGED SOLUTION  
 3 ITERATIONS  
 CRITICAL RANGE IS 7819.60 FT.

(b) Range results Using CRAY VIBRA-6.

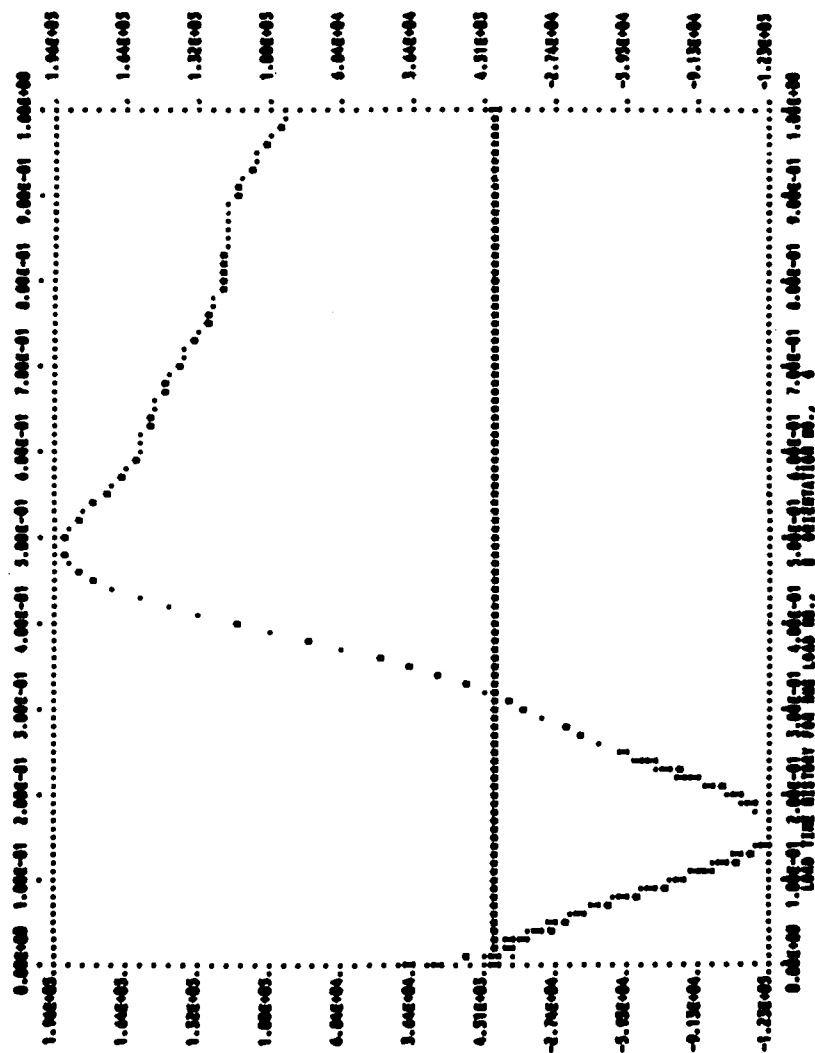
Table 14. (Concluded.)

from the blast run. Range results agree within seven percent, which is considered to be acceptable given the difference in the machines and the iterative nature of the solution. Time histories of load at the critical section are provided in Figure 13 for comparison between the two analyses. Note that the two analyses show the same load time history behavior. Closer correlation between the CRAY and VAX versions might have been obtained had the frequency response module been converted entirely to double precision. However, given the degree of agreement between the versions, this additional step was not considered to be necessary.



(a) Load time history results using VAX VIBRA-6.

Figure 13. Comparison of VAX and CRAY VIBRA-6 load time history results.



(b) Load time history results using CRAY VIBRA-6.

Figure 13. (Concluded.)

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# DEFINITIONS OF NAMES OF COMPUTERS, TERMS, PROGRAMS, PLOTTING PACKAGE, DECKS, AND PROCEDURES

NASTRAN	NASA Structural Analysis Program
VIBRA-6	Vehicle Inelastic Bending Response Analysis Program
COSMIC	NASA's Computer Software Management and Information Center, University of Georgia, Atlanta, Ga
CREATR	Computer program used to create NASTRAN aircraft models
NAS2V6	Computer program which reads NASTRAN OUTPUT2 files and other files generated by CREATR and translates them into VIBRA-6 AERO, IMOD, and LOAD fixed data decks.
AERO	VIBRA-6 aerodynamic model fixed data deck
IMOD	VIBRA-6 inertia model fixed data deck
LOAD	VIBRA-6 loads model fixed data deck
OUTPUT2	NASTRAN output file
NASTPLOT	Plotting package for NASTRAN
RITZ	Procedure for solving eigen values in VIBRA-6
FEER	Procedure for solving eigen values in VIBRA-6
CPU	Central Processor Unit
VAX	Virtual Address Extended, Digital Equipment Corporation computer
VMS	Virtual Memory System
CDC	Control Data Corporation, computer manufacturer
CRAY	CRAY Research Corporation, computer manufacturer

## APPENDIX A

### CREATR INPUT MANUAL

All CREATR input is entered in six fields of twelve columns per record. Floating-point variables begin with letters A through H and O through Z; integers begin with the letters I through N. Avoid errors by right justifying all numeric input (floating point and integer) and left justifying alpha fields.

**Data Set 1.0**  
**CONTROL, TITLE, AND DIMENSIONING INFORMATION**

RECORD	VARIABLE	DESCRIPTION
1	TITLE	Run title, up to 72 characters
2	MTYPE	Model type = BEAM, beam model = PLATE, plate model a la ADAM
3	KSVM	Symmetry flag = 1, Symmetric case only = 2, Antisymmetric case only = 3, Both sym and antisym cases
	KSOL	NASTRAN Solution number = 3, Normal Modes = 10, Modal Flutter
	NMODES	Number of modes to recover
	NSUP	GRID number at which to provide SUPORT = 0, no SUPORT ≠ 0, GRID No.; refer to SUPORT record
	KVIBRA	Flag for VIBRA-6 data creation = 0, create only NASTRAN data ≠ 0, create VIBRA-6 and NASTRAN data
	KRITZ	Ritz procedure flag = 0, do not use Ritz procedure > 0, use Ritz procedure
4	KPLOT	Flag for NASTPLOT plotting = 0, do not create a plot file ≠ 0, create a plot file
	KLOAD	Flag for VIBRA-6 load data deck (ignored if MTYPE = PLATE) = 0, do not create load data (Data Set 14.0) ≠ 0, create load data deck

**Data Set 1.0 — Continued**  
**CONTROL, TITLE, AND DIMENSIONING INFORMATION**

RECORD	VARIABLE	DESCRIPTION
4 (cont)	KEIG	Flag for NASTRAN eigenvalue solution (ignored if KRITZ > 0) = 0, use FEER method > 0, use INVERSE POWER method, get all modes below KEIG Hz.
	NINTLD	Number of integrated beam loads (ignored if KLOAD > 0)
	NENG	Number of centerline and right hand side engines (ignored if KLOAD > 0)
If KRITZ = 0, skip record 5.		
5	KXLOAD	Flag for use of x-direction gravity load to generate initial Ritz vector = 0, do not use x-load ≠ 0, use x-load
	KYLOAD	Flag for use of y-direction gravity load to generate initial Ritz vector = 0, use y-load ≠ 0, do not use y-load
	KZLOAD	Flag for use of z-direction gravity load to generate initial Ritz vector = 0, use z-load ≠ 0, do not use z-load
If MTYPE = PLATE, proceed to record 9.		
6	NTABL	Number of tables in Data Set 2.0
	NMATL	Number of materials in Data Set 4.0
	NSGRD	Number of master structural grids in Data Set 5.0
	NSEL	Number of master structural elements in Data Set 6.0
	NSCS	Number of structural control surfaces in record Set 7.0

**Data Set 1.0 — Continued**  
**CONTROL, TITLE, AND DIMENSIONING INFORMATION**

RECORD	VARIABLE	DESCRIPTION
7	NSPRG	Number of general spring connections in Data Set 8.0
	NCONM	Number of concentrated masses in Data Set 9.0
	NRIGD	Number of rigid connections in Data Set 10.0
8	NPANL	Number of aerodynamic panels in Data Set 11.0
	NBODY	Number of aerodynamic bodies in Data Set 12.0
	NSPLN	Number of splines connecting aero and structure model defined in Data Set 13.0
<b>If MTYPE = BEAM, proceed to Data Set 2.0.</b>		
9	NVALU	Number of constants defined in Data Set 3.0.
	NMATL	Number of materials in Data Set 4.0
	NAIRS	Number of airfoil master elements in Data Set 15.0
	NBDYS	Number of body-type master elements in Data Set 16.0
	NFRMX	Max number of frames in any body defined in Data Set 16.0
	NCON	Number of connection entries in Data Set 17.0
<b>If MTYPE = PLATE, proceed to Data Set 3.0.</b>		

See Notes for Data Set 1.0 on the next page

**Data Set 1.0 — Concluded**  
**CONTROL, TITLE, AND DIMENSIONING INFORMATION**

**NOTES:**

1. TITLE is used on all NASTRAN and VIBRA input files, as well as the CREATR run.
2. KSOL = 10 and KVIBRA  $\neq$  0 are valid only for MTYPE = BEAM.
3. If KRITZ  $\neq$  0, NMODES is the total number of Ritz modes recovered; by default, half will be recovered for an initial Ritz vector derived from gravity load in the y-direction, and half from gravity load in the z-direction. In the aircraft axis system, modes resulting from X (fore-aft) excitation are generally not of interest.
4. There is no limitation on the maximum value of any dimension, except as controlled by the dimension of array M in the main program. The program will abort if this array is not large enough for the input problem, and provide an error message.
5. Minimum permissible values of dimensions are provided in the table below:

For beam models:	For plate models:
NTABL $\geq$ 1	NVALU $\geq$ 1
NMATL $\geq$ 1	NMATL $\geq$ 1
NSGRD $\geq$ 1	NAIRS $\geq$ 0
NSEL $\geq$ 1	NBDYS $\geq$ 0
NSCS $\geq$ 0	NCON $\geq$ 0
NSPRG $\geq$ 0	(NAIRS + NBDYS) $\geq$ 1
NCONM $\geq$ 0	
NRIGD $\geq$ 0	
NPANL $\geq$ 0	
NBODY $\geq$ 0	
NSPLN $\geq$ 0	

**Data Set 2.0**  
**BEAM MODEL TABLE DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat records 1 through 2 for I = 1, NTABL.</b>		
1	NT	Table number
	NTYP	Table type 1 = Global X interpolation 2 = Global Y interpolation 3 = Global Z interpolation 4 = Local axis interpolation
	NENTRY	Number of entries in table number NT
<b>Repeat record 2 for J = 1, NENTRY.</b>		
2	TABL(J,1)	Independent variable
	TABL(J,2)	Dependent variable
<b>Proceed to Data Set 4.0.</b>		

**NOTES:**

1. All beam properties (on a PBAR record) are defined by reference to one of these tables. Properties are then interpolated along the master element length, according to NTYP for the referenced table. Properties which are constant along the master element length must be defined by a table of constant values.
2. For example, if the vertical bending moment of inertia for the wing is to be defined in a table, then the inertia is probably specified in terms of butt line (B.L.). In this case, create a table with the independent variable as inertia, the dependent variable as the B.L. position, and interpolation to be performed along the global y-axis.
3. Global X points aft. Global Y is to the right. Global Z is up.
4. NENTRY must be  $\geq 2$ .

**Data Set 3.0**  
**PLATE MODEL CONSTANT VALUE DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat record 1 for I = 1, NVALU.</b>		
1	IVAL(I)	Constant number
	VALU(I)	Value of constant IVAL(I)
<b>Proceed to Data Set 4.0.</b>		

**NOTES:**

1. All plate thicknesses (on PQDMEM2 and PSHEAR records) are defined by reference to one of these constants. For skins, thicknesses are then interpolated according to the skin gauges at the inboard and outboard edges.

**Data Set 4.0**  
**MATERIAL PROPERTY DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat record 1 for I = 1, NMATL.</b>		
1	IMAT(I)	Material number
	PROP(I,1)	E, Young's modulus
	PROP(I,2)	G, Shear modulus
	PROP(I,3)	XNU, Poisson's ratio
	PROP(I,4)	RHO, Mass density
<b>If MTYPE = BEAM, proceed to Data Set 5.0.</b>		
<b>If MTYPE = PLATE, proceed to Data Set 15.0.</b>		

**NOTES:**

1. See NASTRAN User's manual MAT1 card (record) definition.
2. For plate model composites, material properties are defined for the x- and y-directions by reference to a material number specified here. Shear modulus, G, must be the same for x- and y-directions.

**Data Set 5.0**  
**BEAM MODEL MASTER GRID DEFINITION**

RECORD	VARIABLE	DESCRIPTION
Repeat record 1 for I = 1, NSGRD.		
1	IGRD(I)	Grid number
	XYZ(I,1)	x-coordinate of grid I
	XYZ(I,2)	y-coordinate of grid I
	XYZ(I,3)	z-coordinate of grid I
Proceed to Data Set 6.0.		

**NOTES:**

1. Only global rectangular coordinates are used for master grids.
2. Global X points aft. Global Y is to the right. Global Z is up.

**Data Set 6.0**  
**BEAM MODEL MASTER ELEMENT DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat records 1 through 2 for I = 1, NSEL.</b>		
1	IELN(I)	Element number
	ISEN(I)	Number of subelements to be created
	ICMP(I)	Aircraft component for element IELN(I)
		1 = Wing/H-tail
		2 = Fuselage
		3 = V-tail
		4 = Wing/H-tail pod
		5 = Fuselage pod
		6 = V-tail pod
		7 = Wing/H-tail pylon
		8 = Fuselage pylon
		9 = V-tail pylon
2	IELG(I,1)	Grid 1 of master element
	IELG(I,2)	Grid 2 of master element
	IELM(I)	Material for master element
	IAR(I)	Table number from which to interpolate AREA on PBAR record
	II1(I)	Table number from which to interpolate I1 on PBAR record
	II2(I)	Table number from which to interpolate I2 on PBAR record
	IJ(I)	Table number from which to interpolate J on PBAR record
	INSM(I)	Table number from which to interpolate NSM on PBAR record
<b>Proceed to Data Set 7.0.</b>		

See Notes for Data Set 6.0 on the next page

**Data Set 6.0 — Concluded**  
**BEAM MODEL MASTER ELEMENT DEFINITION**

**NOTES:**

1. NSEL must be  $\geq 1$ .
2. ICMP is used internally to determine local axis definition. II1 always refers to bending in the y-z plane, while II2 always refers to bending in the x-z plane. For planforms, this means that II1 is the out-of-plane bending term and II2 is the in-plane bending term. For the fuselage and pods, II1 is the vertical bending term, and II2 is the lateral bending term.
3. All entries on record 2 must reference existing table numbers and materials.

**Data Set 7.0**  
**BEAM MODEL CONTROL SURFACE DEFINITION**

RECORD	VARIABLE	DESCRIPTION
If NSCS = 0, proceed to Data Set 8.0; otherwise, repeat records 1 through 2 for I = 1, NSCS.		
1	ICSN(I)	Control surface number
	IGR1(1,I)	First hinge line master grid
	IGR1(2,I)	Second hinge line master grid
	IGR2(1,I)	Beam master grid to which first hinge line master grid is attached
	IGR2(2,I)	Beam master grid to which second hinge line master grid is attached
2	XMOI(I)	Mass moment of inertia of control surface about hinge line
	CSKR(I)	Hinge rotational stiffness (per radian)
	ICST(I)	Control surface type 1 = symmetric trim 2 = antisymmetric trim 3 = symmetric and antisymmetric trim
	ICSC(I)	Component to which control surface is attached 1 = wing or horizontal tail 3 = vertical tail
Proceed to Data Set 8.0.		

**NOTES:**

1. Control surface modes are generated separately and placed in a trim mode file for VIBRA-6 use. CSKR should generally be non-zero.
2. Control surfaces can only be attached to the wing, horizontal tail, and vertical tail.

**Data Set 8.0**  
**BEAM MODEL SPRING CONNECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NSPRG = 0, proceed to Data Set 9.0; otherwise, repeat records 1 through 2 for I = 1, NSPRG.</b>		
1	ISPR(I)	Spring connection number
	ISG1(I)	First master grid in connection
	ISG2(I)	Second master grid in connection
2	SPRK(1,I)	Fore-aft spring stiffness
	SPRK(2,I)	Lateral spring stiffness
	SPRK(3,I)	Vertical spring stiffness
	SPRK(4,I)	Roll spring stiffness (units per radian)
	SPRK(5,I)	Pitch spring stiffness (units per radian)
	SPRK(6,I)	Yaw spring stiffness (units per radian)
<b>Proceed to Data Set 9.0.</b>		

**NOTES:**

1. A typical use of springs is for wing root spring definition. In that case, rotational springs [SPRK(4,I) through SPRK(6,I)] are specified between two coincident master grids. Translations between these coincident grids are coupled using the rigid element connection given in Data Set 11.0.

**Data Set 9.0**  
**BEAM MODEL CONCENTRATED MASS DEFINITION**

RECORD	VARIABLE	DESCRIPTION
If NCONM = 0, proceed to Data Set 10.0; otherwise, repeat record 1 for I = 1, NCONM.		
1	ICNM(I)	Concentrated mass number
	IMG(I)	Master grid for concentrated mass
	XMASS(1,I)	Translational mass value
	XMASS(2,I)	Roll inertia value
	XMASS(3,I)	Pitch inertia value
	XMASS(4,I)	Yaw inertia value
Proceed to Data Set 10.0.		

**NOTES:**

1. In cases where a NASTRAN beam model is to be used to generate modal data for VIBRA-6, it is recommended that concentrated masses with significant inertia values (e.g., engines) be modeled using dumbbell-type translational masses separated by rigid elements to account for inertias.

**Data Set 10.0**  
**BEAM MODEL RIGID CONNECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NRIGD = 0, proceed to Data Set 11.0; otherwise, repeat record 1 for I = 1, NRIGD.</b>		
1	IRBN(I)	Rigid connection number
	IRG1(I)	Master grid containing independent dof
	IRG2(I)	Master grid containing dependent dof
	IDOF(I)	Dof at IRG2 which are dependent on displacements at IRG1; any unique combination of digits 1 through 6. 1 = Fore-aft 2 = Lateral 3 = Vertical 4 = Roll 5 = Pitch 6 = Yaw
<b>Proceed to Data Set 11.0.</b>		

**NOTES:**

1. See the NASTRAN theoretical manual for a discussion of rigid elements. The input here is a specialization of the COSMIC/NASTRAN CRIGD2 bulk data record for the aircraft axis system.
2. Master grids IRG1 and IRG2 can be coincident.

**Data Set 11.0**  
**AERODYNAMIC PANEL DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NPANL = 0, proceed to Data Set 12.0; otherwise, repeat records 1 through 5 for I = 1, NPANL.</b>		
1	IPNL(I)	Panel number
	XILE(I)	Inboard leading edge x-coordinate
	XITE(I)	Inboard trailing edge x-coordinate
	XOLE(I)	Outboard leading edge x-coordinate
	XOTE(I)	Outboard trailing edge x-coordinate
2	YIE(I)	Inboard edge y-coordinate
	YOE(I)	Outboard edge y-coordinate
	ZIE(I)	Inboard edge z-coordinate
	ZOE(I)	Outboard edge z-coordinate
3	NCBOX(I)	Number of chordwise boxes > 0, NCBOX equal divisions < 0, fractions on record 4
	NSBOX(I)	Number of spanwise boxes > 0, NSBOX equal divisions < 0, fractions on record 5
	IGRUP(I)	Group number of panel
<b>If NCBOX(I) ≤ 0, repeat record 4 for J = 1, ABS(NCBOX(I)+1); otherwise proceed to record 5.</b>		
4	TH(J)	Fractional chordwise divisions for panel (6 per record). Typically ranging from 0.0 at the leading edge to 1.0 at the trailing edge.
<b>If NSBOX(I) ≤ 0, repeat record 5 for J = 1, ABS(NSBOX(I)+1); otherwise proceed to Data Set 12.0.</b>		
5	TAU(J)	Fractional spanwise division for panel (6 per record). Typically ranging from 0.0 at the inboard edge to 1.0 at the outboard edge.
<b>Proceed to Data Set 12.0.</b>		

See Notes for Data Set 11.0 on the next page

**Data Set 11.0 — Concluded**  
**AERODYNAMIC PANEL DEFINITION**

**NOTES:**

1. NCBOX and NSBOX must be  $\geq 2$ .
2. When KVIBRA  $\neq 0$ , the actual panel generated by CREATR for NASTRAN will be a pseudopanel used to define the panel corner points only. See the discussion in the report body.

**Data Set 12.0**  
**AERODYNAMIC BODY DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NBODY = 0, proceed to Data Set 13.0; otherwise, repeat records 1 through 7 for I = 1, NBODY.</b>		
1	IBDY(I)	Body number
	NBE(I)	Number of interference body elements
	NSBE(I)	Number of slender body elements
	NRI(I)	Interference radius flag = 1, RI array is input = 0, RI(I) = A0, for all I = 1, NBE+1
	NRS(I)	Slender body radius flag = 1, RS array is input = 0, RS(I) = A0, for all I = 1, NSBE+1
	NT1(I)	Number of entries in the TH1 array
2	ZC(I)	Z coordinate of body axis
	YC(I)	Y coordinate of body axis
	A0(I)	Avg semi-width of interference body
	AR(I)	Cross sectional aspect ratio (height/width)
<b>Repeat record 3 for J = 1, NBE+1.</b>		
3	XII(J)	X coordinates of interference body endpoints (6 per record).
<b>If NRI(I) &gt; 0, repeat record 4 for J = 1, NBE+1; otherwise, skip to record 5.</b>		
4	RI(J)	Semi-widths or radii of interference body element endpoints (6 per record).
<b>Repeat record 5 for J = 1, NT1.</b>		
5	TH1(J)	Angular orientation of points on interference body surface, degrees (6 per record).

**Data Set 12.0 — Concluded**  
**AERODYNAMIC BODY DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat record 6 for <math>J = 1, NSBE+1</math>.</b>		
6	XIS(J)	X coordinates of slender body endpoints (6 per record). Typically starting with 0.0 at the nose.
<b>If <math>NRS &gt; 0</math>, then repeat record 7 for <math>J = 1, NSBE+1</math>; otherwise, proceed to Data Set 13.0.</b>		
7	RS(J)	Semi-widths or radii of slender body endpoints (6 per record).
<b>Proceed to Data Set 13.0.</b>		

**NOTES:**

1. If NRI or NRS is zero, A0 must be non-zero.
2. When KVIBRA  $\neq 0$ , the actual body generated by CREATR for NASTRAN will be a pseudobody used to define the body end points only. See the discussion in the report body.

**Data Set 13.0**  
**AERO-STRUCTURAL MODEL SPLINE DEFINITION**

RECORD	VARIABLE	DESCRIPTION
If NSPLN = 0, proceed to Data Set 14.0; otherwise, repeat record 1 for I = 1, NSPLN.		
1	ISPLN(I)	Spline number
	IMEL(I)	Master structural element number or control surface number for this spline
	IAER(I)	Aerodynamic panel or body number for this spline
	IBOXI(I)	initial box or body element of IAER(I) for which displacements will be interpolated
	IBOXF(I)	Final box or body element of IAER(I) for which displacements will be interpolated
Proceed to Data Set 14.0.		

**NOTES:**

1. Splines must reference existing master element and aerodynamic element numbers.
2. Box range is local to the aerodynamic element being splined to; i.e., must be  $\leq$  NCBOX\*NSBOX for a panel and  $\leq$  NSBE for a slender body.

**Data Set 14.0**  
**VIBRA-6 LOAD DATA DECK DEFINITION**

RECORD	VARIABLE	DESCRIPTION
If KLOAD = 0, this is the end of input for CREATR. Do not input Data Set 14.0 or any of the remaining sets.		
Repeat records 1 and 2 for I = 1, NINTLD.		
1	IBEAM(I)	Master element number for load recovery
	LCODE(I)	Load code (same as VIBRA-6 variable CODEL) 1 = Mx 2 = My 3 = Mz 4 = Px 5 = Py 6 = Pz
2	XLOAD(I)	XAAS coordinate of integrated load
	YLOAD(I)	YAAS coordinate of integrated load
	ZLOAD(I)	ZAAS coordinate of integrated load
	PMAX(I)	Maximum allowable positive load
	PMIN(I)	Maximum allowable negative load (< 0)
Repeat record 3 for I = 1, NSGRD.		
3	IGR2BM(1,I)	Master grid number
	IGR2BM(2,I)	Master element number with which inertia loads at master grid IGR2BM(1,I) are associated.
Repeat record 4 for I = 1, NENG.		
4	MENG(1,I)	First master grid defining the engine
	MENG(2,I)	Second master grid defining the engine, where thrust acts at MENG(1,I) along a vector from MENG(2,I) to MENG(1,I).

**Data Set 14.0 — Concluded**  
**VIBRA-6 LOAD DATA DECK DEFINITION**

RECORD	VARIABLE	DESCRIPTION
5	MTBOX	Number of aero boxes for aero load time histories.
	MTSBE	Number of aero slender body elements for aero load time histories.
If MTBOX $\leq$ 0, skip record 6; otherwise, repeat record 6 for I = 1, MTBOX.		
6	NBOXP(1,I)	Aero panel number for pressure recovery
	NBOXP(2,I)	Box number on aero panel NBOXP(1,I) at which pressure time history will be recovered.
If MTSBE $\leq$ 0, skip record 7; otherwise, repeat record 7 for I = 1, MTBOX.		
7	NSBEP(1,I)	Aero slender body number for pressure recovery.
	NSBEP(2,I)	Element number on slender body NSBEP(1,I) at which pressure time history will be recovered.
If MTYPE = BEAM, this is the end of input for CREATR. Do not input any of the remaining Data Sets.		

**NOTES:**

1. The VIBRA-6 load code orientation convention is used.
2. A cross-reference between every master grid and a single master element must be provided (record 3) so that the inertia or mass load in the VIBRA-6 analysis can be assigned to a beam in the loads model.
3. Panel box numbers and slender body element numbers specified for pressure recovery (records 6 and 7) are local to the panel and body (i.e., must be  $\leq$  NCBOX\*NSBOX for the panel and NSBE for the body).

**Data Set 15.0**  
**PLATE-TYPE AIRFOIL SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NAIRS = 0, proceed to Data Set 16.0; otherwise, repeat records 1 through 27 for I = 1, NAIRS.</b>		
1	IELA(I)	Airfoil master element number
	XOB(I)	X coordinate of airfoil apex point
	YOB(I)	Y coordinate of airfoil apex point
	ZOB(I)	Z coordinate of airfoil apex point
2	CR0(I)	Root chord of the airfoil
	S0(I)	Semi-span of the airfoil
	AL0(I)	Leading edge sweep angle, degrees
	AT0(I)	Trailing edge sweep angle, degrees
	ANG0(I)	Angle that ribs make with x-axis, degrees
	WNGDIH(I)	Wing dihedral angle, rotated about apex, degrees
3	NRB(I)	Number of ribs in this airfoil
	NSP(I)	Number of spars in this airfoil
<b>Repeat record 4 for J = 1, NRB.</b>		
4	ANRB(J)	Angle of rib J, referenced from the first spar at rib J, degrees. Rib J is rotated ANG0 degrees and modified by ANRB(J). (6 per record).
<b>Repeat record 5 for J = 1, NRB.</b>		
5	RN(J)	Location of Rib J, as a fraction of the semi-span, referenced from the root chord. (6 per record).
<b>Repeat record 6 for K = 1, NSP.</b>		
6	SP(K)	Location of Spar K, as a fraction of the chord, referenced from the leading edge. (6 per record).

**Data Set 15.0 — Continued**  
**PLATE-TYPE AIRFOIL SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
7	NSYM(I)	Box vertical symmetry flag = -1, symmetric section, only top surface z-coords will be input. = 0, nonsymmetric section, top and bottom surface z-coords will be input
	ZTYPE(I)	Z coordinate dimension type flag = 0, z-coords are normalized by the chordlength = 1, z-coords have actual length units
Repeat record 8 for K = 1, NSP.		
8	Z1(K,1)	Top surface z-coords for the first rib, specified at each spar K. (6 per record).
Repeat record 9 for K = 1, NSP.		
9	Z1(K,NRB)	Top surface z-coords for the last rib, specified at each spar K. (6 per record).
If NSYM = 0, repeat record 10 for K = 1, NSP.		
10	Z2(K,1)	Bottom surface z-coords for the first rib, specified at each spar K. (6 per record).
If NSYM = 0, repeat record 11 for K = 1, NSP.		
11	Z2(K,NRB)	Bottom surface z-coords for the last rib, specified at each spar K. (6 per record).
12	IRBROT(I)	Rib rotation flag, = 0, all ribs are rotated = 1, rotate all but the first rib

**Data Set 15.0 — Continued**  
**PLATE-TYPE AIRFOIL SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
13	IPGAGA(I)	Number of constant (IVAL) used to specify rib and spar cap thickness
	IPMATA(I)	Material number (IMAT) for rib and spar caps
14	IRGAG(I)	Number of constant (IVAL) used to specify rib thickness
	IRMAT(I)	Material number (IMAT) for ribs
15	ISGAG(I)	Number of constant (IVAL) used to specify spar thickness
	ISMAT(I)	Material number (IMAT) for spars
16	ICGAGA(I)	Number of constant (IVAL) used to specify top inboard skin thickness > 0, reference to IVAL in Data Set 3.0 < 0, flag to indicate skin is composite
	ICMATA(I)	Material number (IMAT) for skin > 0, reference to IVAL in Data Set 3.0 < 0, flag to indicate skin is composite
17	IDGAG(I)	Number of constant (IVAL) used to specify top outboard skin thickness > 0, reference to IVAL in Data Set 3.0 < 0, flag to indicate skin is composite
	IEGAG(I)	Number of constant (IVAL) used to specify bottom inboard skin thickness > 0, reference to IVAL in Data Set 3.0 < 0, flag to indicate skin is composite
18	XNSMA(I)	non-structural mass for skin
<b>Repeat record 19 for J = 1, NRB.</b>		
19	IRTYPE(J)	Rib type flag (6 per record). = 0, do not generate elements for this rib = 1, do generate elements for this rib

**Data Set 15.0 — Concluded**  
**PLATE-TYPE AIRFOIL SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>Repeat record 20 for K = 1, NSP.</b>		
20	ISTYPE(K)	Spar type flag (6 per record). = 0, do not generate elements for this spar = 1, do generate element for this spar
<b>If ICGAGA is <math>\leq 0</math>, continue input with record 21; otherwise, record 20 is the end of input for element I.</b>		
21	NELT(I)	Number of elements in the layup
	TREFA(I)	Reference angle for top skin, relative to positive x-axis, degrees
	BREFA(I)	Reference angle for bottom skin, relative to positive x-axis, degrees
<b>Repeat record 22 for J = 1, NELT(I).</b>		
22	TTHICK(J)	Thickness of layer J of top skin (6 per record).
<b>Repeat record 23 for J = 1, NELT(I).</b>		
23	BTHICK(J)	Thickness of layer J of bottom skin (6 per record).
<b>Repeat record 24 for J = 1, NELT(I).</b>		
24	TTHETA(J)	Fiber orientation of layer J of top skin (6 per record).
<b>Repeat record 25 for J = 1, NELT(I).</b>		
25	BTHETA(J)	Fiber orientation of layer J of bottom skin (6 per record).
<b>Repeat record 26 for J = 1, NELT(I).</b>		
26	MATLX(J)	Material number (IMAT) describing x-direction properties of layer J (6 per record).
<b>Repeat record 27 for J = 1, NELT(I).</b>		
27	MATLY(J)	Material number (IMAT) describing y-direction properties of layer J (6 per record).
<b>Proceed to Data Set 16.0.</b>		

**Data Set 16.0**  
**PLATE-TYPE BODY SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
<b>If NBDYS = 0, proceed to Data Set 17.0; otherwise, repeat records 1 through 13 for I = 1, NBDYS.</b>		
1	IELB(I)	Body master element number
	XOB(I)	X coordinate of body apex point
	YOB(I)	Y coordinate of body apex point
	ZOB(I)	Z coordinate of body apex point
2	NFRAME(I)	Number of frames in this body
	NANGLE(I)	Number of angles in this body
<b>Repeat records 3 through 6 for J = 1, NFRAME.</b>		
3	XFRAME(J)	X position of frame J
	CAMBER(J)	Camber for frame J
<b>Repeat record 4 for K = 1, NANGLE.</b>		
4	ANGLE(K)	Angle position for angle K, frame J, degrees (6 per record).
<b>Repeat record 5 for K = 1, NANGLE.</b>		
5	ROUTER(K)	Outer surface radius for angle K, frame J (6 per record).
<b>Repeat record 6 for K = 1, NANGLE.</b>		
6	RINNER(K)	Inner surface radius for angle K, frame J (6 per record).
7	IPGAGB(I)	Number of constant (IVAL) used to specify frame and angle cap thickness
	IPMATB(I)	Material number (IMAT) for frames and angles

**Data Set 16.0 — Concluded**  
**PLATE-TYPE BODY SECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
8	IFGAG(I)	Number of constant (IVAL) used to specify frame thickness
	IFMAT(I)	Material number (IMAT) for frames
9	IAGAG(I)	Number of constant (IVAL) used to specify angle thickness
	IAMAT(I)	Material number (IMAT) for angles
10	ICGAGB(I)	Number of constant (IVAL) used to specify skin thickness
	ICMATB(I)	Material number (IMAT) for skin
11	XNSMB(I)	Non-structural mass for skin
<b>Repeat record 12 for J = 1, NFRAME.</b>		
12	IFTYPE(J)	Frame type flag (6 per record). = 0, do not generate elements for this frame = 1, do generate elements for this frame
<b>Repeat record 13 for K = 1, NANGLE.</b>		
13	IATYPE(K)	Angle type flag (6 per record). = 0, do not generate elements for this angle = 1, do generate element for this angle
<b>Proceed to Data Set 17.0</b>		

**Data Set 17.0**  
**PLATE-TYPE SECTION CONNECTION DEFINITION**

RECORD	VARIABLE	DESCRIPTION
If NCON = 0, this is the end of input for CREATR; otherwise, repeat records 1 through 2 for I = 1, NCON.		
1	IRBODY(I)	Number of element (body or airfoil) containing grids to be retained
	IRRIBI(I)	initial rib/frame containing grids to be retained on body IRBODY
	IRSPRI(I)	initial spar/angle containing grids to be retained on body IRBODY
	IRSURF(I)	Surface containing grids to be retained on body IRBODY, = 0, top/outer surface = 1, bottom/inner surface
	IRRIBF(I)	Final rib/frame containing grids to be retained on body IRBODY
	IRSPRF(I)	Final spar/angle containing grids to be retained on body IRBODY
2	IEBODY(I)	Number of element (body or airfoil) containing grids to be eliminated
	IERIBI(I)	initial rib/frame containing grids to be eliminated on body IEBODY
	IESPRI(I)	initial spar/angle containing grids to be eliminated on body IEBODY
	IESURF(I)	Surface containing grids to be eliminated on body IEBODY, = 0, top/outer surface = 1, bottom/inner surface
	IERIBF(I)	Final rib/frame containing grids to be eliminated on body IEBODY
	IESPRF(I)	Final spar/angle containing grids to be eliminated on body IEBODY

## APPENDIX B

### NAS2V6 INPUT MANUAL

All NAS2V6 input is entered in six fields of twelve columns per record. Floating-point variables begin with letters A through H and O through Z; integers begin with the letters I through N. Avoid errors by right justifying all numeric input (floating point and integer) and left justifying alpha fields.

# NAS2V6 INPUT

RECORD	VARIABLE	DESCRIPTION	Grp/Item
Variables on records 1-5 have the same names and definitions as given in the the VIBRA-6 documentation, and a cross-reference back to VIBRA-6 group/item numbers is provided. A-X/Y is Aero Group X, Item Y, and I-X/Y is IMOD Group X, Item Y.			
1	MFIX1	Mode number of first mode to monitor	A-1/2
	MFIX2	Mode number of last mode to monitor	A-1/2
	IPR1	Print flag for normalwash and gust boundary conditions	A-1/7
	IPR2	Print flag for point forces that are saved on VIBRA-6 aero Data file	A-1/7
	IPR3	Print flag for pressures, body loadings and downwash factors	A-1/7
	KPRINT	Print flag for H and DHDX matrices	A-4/1
2	FMACH	Mach number, usual definition	A-1/9
	REFA	Reference area, usually total area of both wings	A-1/9
	REFS	Reference semispan	A-1/9
	REFC	Reference chord, usually average chord of wing	A-1/9
	XM	Moment axis	A-1/9
	SCALER	Nondimensional image radius	A-1/9
3	NKD	Number of reduced frequencies for doublet lattice calculations	A-1/8
Repeat record 4 for I = 1, NKD.			
4	FREQ(I)	Reduced frequencies (6 per record)	A-1/10
5	NENGs	Number of engines on right side and centerline	I-1/2
	KPRLDS	Print flag for unit load matrices	I-1/2
6	NSYM0	Number of symmetric modes from symmetric NASTRAN run	A-1/2
	NASYM0	Number of antisymmetric modes from antisymmetric NASTRAN run	A-1/2

# **NAS2V6 INPUT — Concluded**

RECORD	VARIABLE	DESCRIPTION	Grp/Item
<b>If NSYM0 = 0, skip to record 9.</b>			
7	MOD1	Number of rigid body plunge mode	I-1/5
	MOD2	Number of rigid body pitch mode	I-1/5
	MOD3	Number of rigid body fore/aft mode	I-1/5
	MOD4	Number of first symmetric elastic mode	I-1/5
	MOD5	Number of last symmetric elastic mode	I-1/5
<b>Repeat record 8 for I = 1, NSYM0.</b>			
8	SDPG(I)	Symmetric modes modal damping ratio (6 per record).	I-1/6
<b>If NASYM0 = 0, this is the end of the user-supplied input; otherwise, continue on to records 9 and 10.</b>			
9	MOD11	Number of rigid body roll mode	I-1/5
	MOD12	Number of rigid body yaw mode	I-1/5
	MOD13	Number of rigid body lateral mode	I-1/5
	MOD14	Number of first antisymmetric elastic mode	I-1/5
	MOD15	Number of last antisymmetric elastic mode	I-1/5
<b>Repeat record 10 for I = 1, NASYM0.</b>			
10	ADPG(I)	Antisymmetric modes modal damping ratio (6 per record).	I-1/6

## **NOTES:**

1. NSYM0 and NASYM0 do not include trim modes. They refer only to the number of NASTRAN-output modes to be used in the VIBRA-6 run.
2. Mode numbers given on records 7 and 9 refer to the output order of modes in the NASTRAN symmetric and antisymmetric runs. For example, if the rigid body plunge mode which falls out of the symmetric run was the 3rd mode printed in the output for that run, MOD1 = 3. If the rigid body roll mode which falls out of the antisymmetric run was the 2nd mode printed in the output for that run, MOD11 is input as 2. This style differs from VIBRA-6, and the program will make the necessary translations and insert the trim modes as required.

## APPENDIX C

### TRIM MODE FILE DEFINITION

The trim mode file is automatically generated by CREATR when control surfaces are specified in input (Data Set 7.0). In certain cases, however, as when an entire panel rotates about some arbitrary-axis, the user must input a trim mode manually. For this reason, the form of the trim mode file is defined in this section. In most cases, users will simply be adding a mode to the file, not creating it from scratch.

To add a mode, go to the CREATR output file, and identify the panel which generates the new trim mode. CREATR supplies a list of the panel corner grid points and their XYZ locations in space. Compute the radii from the axis of rotation to the corner grids for the panel, and then input the trim mode according to the format described in the subsequent table. An illustration of the approach was shown in Figure 10.

As in all CREATR/VIBRA-6/NAS2V6 input, data are entered in six fields of twelve columns per record. Floating point variables begin with letters A through H and O through Z; integers begin with the letters I through N. Avoid errors by right justifying all numeric input (floating point and integer) and left justifying alpha fields.

### TRIM MODE FILE DEFINITION

RECORD	VARIABLE	DESCRIPTION
Repeat records 1 and 2 for as many trim modes as necessary.		
1	ITYPE	Type of trim mode = 1, Mode defined on record 2 is a pitch trim mode = 2, Mode defined on record 2 is a roll trim mode = 3, Mode defined on record 2 is a yaw trim mode
Repeat record 2 for I = 1, 4.		
2	NODE(I) DISP(I)	NASTRAN aero GRID number for corner I Normal (out-of-plane) displacement of NODE(I) for a one radian rotation of the control surface described in this mode.

#### NOTES:

1. trim modes and grid numbers can be input in any order.
2. Refer to Figure 11 for an example of trim mode input.

## APPENDIX D

### SOFTWARE DISTRIBUTION TAPE AND INSTALLATION INSTRUCTIONS

This Appendix describes the distribution tape and installation instructions for the computer programs for generation of NASTRAN and VIBRA-6 Aircraft Models.

#### D.1 INSTALLATION INSTRUCTIONS

The tape is written using the BACKUP utility under VMS 4.5. Because of the large amount of data, distinct sets of files are written to different save set names using BACKUP. This approach facilitates selective unloading of data. For example, the VIBRA-6 source code is quite lengthy, and the user may not want it on the system; therefore, it is provided under a separate save set than the executable.

The save sets are shown below in the order of their appearance on the tape:

Save Set Name	Description
INSTALL	Installation command file and instructions.
COM	Command file for executing all programs; also, a small FORTRAN code for scanning execution histories.
CREATR	CREATR executable, source, etc.
NAS2V6	NAS2V6 executable, source, etc.
RITZ	Ritz procedure source, etc.
V6EXE	VIBRA-6 executable and command files to link new versions.
F18	F18 sample problems described in Section 7.1.
PLATE	Plate model sample problems described in Section 7.2.
V6SRC	VIBRA-6 source, text and object libraries.
TRANSP	Transport aircraft sample problem input (described in Section 7.3).

To install the programs, follow this procedure, where Mxxx: refers to the name of the tape drive on the system:

- Mount the tape on the drive, place it on-line and issue the command:  
\$ MOUNT/FOREIGN Mxxx:
- Put the installation command file and instructions on the system  
\$ BACKUP/REWIND/LOG Mxxx:INSTALL \*
- Print or look at the installation instructions file, INTALL.TXT. Then, *edit* INSTALL.COM and *replace the destination directories for all save sets.*

- To install all the save sets at once, issue the command:

`$ @INSTALL`

- To install a single save set, issue the command:

`$ @INSTALL savesetname`

where `savesetname` is the one the user wants.

- *Don't forget to edit the command files in save set COM to point to the proper directories.*

## D.2 DISTRIBUTION TAPE CONTENTS

This section contains a partial listing of the file `INSTALL.TXT` on the distribution tape. The tape contains files in ten save sets. The programs were all developed, modified or used under ASIAC Problem 4.2-04, VIBRA-Ritz.

The following naming conventions are used for all files:

- .BAT — DCL Command file for batch execution only
- .COM — DCL command file
- .CRY — CRAY FORTRAN source file
- .DAT — Data file, can be text or binary depending on application.
- .DAY — Dayfile from COSMIC/NASTRAN run
- .DIR — Directory
- .EXE — Executable code
- .FOR — FORTRAN source code
- .INP — Input file, text
- .LIS — FORTRAN compilation listing
- .MIS — Machine independent source for NASTRAN user module
- .NID — COSMIC/NASTRAN input deck
- .OBJ — Object code
- .OLB — Object library file
- .OUT — Output file, text
- .TLB — Text library file
- .TXT — Text file like this

All interactive and batch executions of `CREATR`, `COSMIC/NASTRAN`, `NAS2V6`, and `VIBRA-6` can be accomplished through a command file in save set `COM` which uses its own file naming convention. The user specifies a run id for the current analysis. This run id could be something like `F18`, or `B52`, or `F111`. The input files for this run

id are assumed to be named as follows:

runid_CRE.INP	CREATR input file
runid_N2V.INP	NAS2V6 input file
runid_RDD.DAT	VIBRA-6 run data deck

Assuming the user creates the NASTRAN input with CREATR and the VIBRA-6 fixed data deck with NAS2V6, the command file handles all other file assignments and naming conventions. The user has only to be aware of the above three naming conventions. Unfortunately, there will be cases where the user will want to add things to the CREATR-produced NASTRAN input files, and so on. In these cases, the user will want to know what the files are named and which run created them; they are all identified as follows:

#### CREATR RUN

Input Files	runid_CRE.INP	
Output Files	runid_CRE.OUT	Printed output
	runid_SYM.NID	NASTRAN symmetric input deck
	runid_ASY.NID	NASTRAN antisym input deck
	runid_AUX.DAT	Aux file used later as input to NAS2V6
	runid_CTL.DAT	Control file used later as input to NAS2V6
	runid_TRM.DAT	trim modes file used later as input to NAS2V6
	runid_LDD.DAT	VIBRA-6 load data deck

#### SYMMETRIC NASTRAN RUN

Input Files	runid_SYM.NID	
Output Files	runid_SYM.OUT	Printed output
	runid_SYM.DAY	Dayfile, normally FOR004
	runid_BGS.DAT	BGPDT data block OUTPUT2 file
	runid_CSS.DAT	CSTM data block OUTPUT2 file
	runid_EQS.DAT	EQEXIN data block OUTPUT2 file
	runid_LAS.DAT	LAMA data block OUTPUT2 file
	runid_MGS.DAT	MGG diagonal OUTPUT2 file
	runid_PHS.DAT	PHIA data block OUTPUT2 file

### ANTISYMMETRIC NASTRAN RUN

Input Files	runid_ASY.NID	
Output Files	runid_ASY.OUT	Printed output
	runid_ASY.DAY	Dayfile, normally FOR004
	runid_BGA.DAT	BGPDT data block OUTPUT2 file
	runid_CSA.DAT	CSTM data block OUTPUT2 file
	runid_EQA.DAT	EQEXIN data block OUTPUT2 file
	runid_LAA.DAT	LAMA data block OUTPUT2 file
	runid_MGA.DAT	MGG diagonal OUTPUT2 file
	runid_PHA.DAT	PHIA data block OUTPUT2 file

### NAS2V6 RUN

Input Files	runid_N2V.INP	
	All .DAT files from both NASTRAN runs	
	All .DAT files from CREATR run	
Output Files	runid_N2V.OUT	Printed output
	runid_FDD.DAT	Complete VIBRA-6 fixed data deck

### VIBRA-6 RUN

Input Files	runid_RDD.DAT	run data deck
	runid_FDD.DAT	fixed data deck
Output Files	runid_VIB.OUT	Printed output
	runid_AER.DAT	Aerodynamic Data file
	runid_FRS.DAT	Frequency response file
	runid_GUS.DAT	Unit gust loads file
	runid_LOD.DAT	Unit loads file

Some scratch files are also opened for these runs, but are not left on the directory when execution is complete.

A listing of all save sets is provided on the tape, with appropriate identification; however, the listing is not provided in this report.

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